JOINT PAINT REMOVAL STUDY

JOINT POLICY COORDINATING GROUP ON DEPOT MAINTENANCE
TASKING DIRECTIVE 1-90

FINAL REPORT ON

PLASTIC MEDIA BLASTING

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FOREWORD

This is the final report for Plastic Media Blasting (PMB). The report is the first of five individual studies directed by the Joint Policy Coordinating Group on Depot Maintenance Tasking Directive 1-90.

The report generalizes on the whole PMB program and the information as it exists at this time. The amount of data pertaining to PMB testing is voluminous, and considerable knowledge and expertise has been developed in many aspects of the process since the original work. The reader is urged to review pertinent test reports as listed in Appendix II.

Points of contact for the Joint Paint Removal Study are in Appendix IV.

EXECUTIVE SUMMARY

BACKGROUND:

The Joint Policy Coordinating Group on Depot Maintenance (JPCG-DM) tasked the Joint Technology Exchange Group (JTEG) to conduct a study of alternative paint removal processes that have potential use within the DOD depot maintenance community. Tasking Directive 1-90 was signed by the JPCG-DM on 19 Dec 89 (Appendix I). The JTEG was directed to plan and manage the study, identify the techniques to be studied, sponsor/advocate research and development initiatives, oversee joint Service testing, evaluate the study, and report the results.

OBJECTIVE:

The objective of the study is to give managers coordinated joint Service technical and management information to help them make investment and application decisions regarding current and emerging paint removal processes. This is to be accomplished by identifying and evaluating alternative paint removal processes, while eliminating duplicate developmental efforts.

SCOPE:

To realize the quickest benefits, five paint removal processes were studied: PMB, laser, sodium bicarbonate blasting, carbon dioxide pellet blasting, and high pressure water blasting. To reduce costs and time frames, testing was conducted at facilities that had already established or begun efforts to establish organic capability.

STUDY PLAN:

The study was conducted in three phases. Phase I consisted of a comprehensive review, within DOD, to identify existing capabilities/plans and to establish a baseline for the study. The baseline, which related to the five alternatives, included identifying current capabilities, degree of maturity for each method, developmental efforts and time frames, and study criteria. Also, from the baseline data, lead activities were recommended and study teams established. Phase II is the feasibility, testing, and analysis phase, which was begun by designating lead activities and developing a coordinated plan for each process to include economic, environmental, and technical evaluations. During Phase II, the status of each alternative process was reported periodically to the JPCG-DM and the depot maintenance community. Phase III is the analysis and documentation phase. For each process, an interim report will be provided as testing is completed. Following the completion of all sub-studies, a final report will provide a comparative analysis.

SUMMARY FOR PLASTIC MEDIA BLASTING:

PMB has been developed, used, and improved for several years. Therefore, the PMB study is as much an effort to document testing that has already been done, and to assemble data, as it is to identify current developments. Ogden Air Logistics Center (OO-ALC), Hill AFB, Ogden, UT, accepted "lead depot" responsibility for thin skin PMB application. Naval Aviation Depot (NADEP), Marine Corps Air Station (MCAS) , Cherry Point, NC, became the lead depot for composite application and Puget Sound Naval Shipyard (NSY), Bremerton, WA, for heavy iron application. This report summarizes the individual reports from these activities and the PMB Technical Report from Wright Laboratories, Wright-Patterson AFB, OH, which was initially disseminated and reviewed by the Services as the "Draft Air Force Systems Command Design Handbook."

Generally, PMB has been accepted by all the Services as a viable alternative paint stripping method and as a replacement for mechanical or chemical methods. There has been in-depth, long-term testing of the PMB process where suitable blasting parameters, blasting equipment, and training programs have been developed. Acrylic, type V, plastic media has emerged as the best available media for stripping thin, soft aluminum alloys. However, for non-aircraft applications such as shipping containers, ground equipment, and trucks, where there is less concern about fatigue life reduction possibilities, more aggressive media, such as type III (melamine) and type II (urea) support higher production rates. Many of the users view the PMB process as an interim method for use until improved alternative methods and materials are developed for implementation.

All Service maintenance depots have built specially designed equipment and facilities for aircraft paint stripping. Still, the PMB process has limits for use on delicate substrates and drawbacks, such as the requirement for dedicated facilities and, for specific applications, the total process time and costs. For example, total process times are increased when media intrusion problems create additional steps in the stripping process. These include masking the structure and removing paint from the masked areas. A feature that is considered to be a benefit at one activity may be an area of concern at another because of variations in hardware, operator training and demonstrated skill, media cleanliness and process parameter controls required in the use of blast equipment, media filtration, and delivery systems.

Even though PMB has been used for several years, testing continues as new materials and equipment are developed. Also, as new programs start up for stripping aircraft skins and substructures, the recommendation is that the impact of the specific process be assessed by using methods previously reported or by other suitable means, such as testing, to determine if the inspection intervals need to be revised.

For PMB use on soft metals such as 2024-T3 aluminum alloy and aircraft structures the primary concern is an increase in fatigue crack growth rate. If fatigue cracks are recognized and uncorrected by adjusting the inspection intervals, aircraft safety could be jeopardized. Secondary concerns are for reducted fatigue initiation life at locations other than fastener holes, and slight damage to alclad coatings.

PMB testing is not complete on composite materials. However, using type V media, acceptable stripping can be accomplished if an item is only stripped to the primer, leaving the primer on the surface to protect it and the substrate.

PMB, as an alternative to chemical paint stripping, generates much less hazardous waste. However, even nonhazardous waste presents a large volume of solid waste for disposal. With PMB there is very little rinsing of the stripped substrate and there are no toxic substances handled. The major problem is plastic dust with paint chips intermingled. Disposal options include solidifying the plastic dust and dumping it in appropriate land fills, burning it in approved hazardous material incinerators, or using it as a fuel additive in authorized cement kilns. Other alternatives are paying media supplier to take the waste media back for recycling or using biologic agents, bacteria, and fungi that will readily attack paint chips within the plastic media or, as with acrylic media, will bio-degrade the plastic.

PMB, even with its many drawbacks, is the most effective nonchemical coating removal system, with broad application, currently available and acceptable for use.

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SECTION I - OVERVIEW OF PLASTIC MEDIA BLASTING

1.1 INTRODUCTION

1.1.1 Paint coatings are applied, maintained, removed, and replaced for a variety of reasons. They provide identification and markings, protection against corrosion, visual and electronic camouflage, thermal protection, erosion resistance, and decorative qualities. For fiberglass, graphite, boron, kevlar, or other composite material systems, paint coatings also provide a barrier protecting the matrix resin material from degradation due to moisture, environmental conditions, and ultraviolet light effects.

1.1.2 Chemical paint removal technology has been relatively stable since the advent of nonflammable methylene chloride-based paint strippers. When zinc chromate (alkyd primers), lacquer (acrylic nitrocellulose), or enamel (alkyd) topcoats were used, the methylene chloride strippers quickly and efficiently removed the coatings from metallic substrates. Unfortunately, the lacquer and enamel coatings are susceptible to degradation from abrasion, erosion, weathering, and incompatibility with aircraft fluids, lubricants, and fuels. The military service life of these older paint systems was only one or two years and they required continual inspection, maintenance, and touch-up. As coatings improved, they transitioned from lacquers and enamels to epoxies, polyurethanes, and fluropolymers. The traditional methylene chloride-based paint strippers added activators, typically consisting of phenols, formic acid, or amine, to enhance removal. Environmental and safety hazards associated with chemical strippers created pressure to seek alternative, less expensive, less toxic, and nonhazardous waste generating processes in the depainting industry. Additionally, organic matrix composites, such as graphite/epoxy, boron/epoxy, and fiberglass, are now routinely incorporated into aircraft structure. These advanced composite surfaces generally are susceptible to degradation from chemical strippers absorbed into the matrix resin system, causing loss of mechanical properties. However, many composite parts are routinely stripped with chemicals applied for short durations and then mechanically scraped clean of paint and chemical residue before final hand sanding and repainting.

1.1.3 PMB is an accepted alternative depainting method that has been studied extensively since the early 1980s to evaluate coating removal effectiveness versus the imparted residual peening effects on material substrates. Plastic blasting media is ranked by hardness, density, and physical chemistry. The most common media types presently used include acrylic thermoplastic (type V_l), acrylic thermoset (type V_x), urea formaldehyde (type II), melamine (type III) and polyester (type I) resins. While all of these media have been used, the predominate aerospace blasting media is type V_l, acrylic thermoplastic. This media, which has replaced type II for use on airframes at Hill AFB, UT, and type I at McClellan AFB, CA, was used at Kelly AFB, TX; Williams AFB, AZ; Randolf AFB, TX; US Army Helicopter Repair Depot in Corpus Christi, TX; NADEP Pensacola, FL; NADEP Cherry Point, NC; and other depots. Many paint stripping facilities that require high production rates have adopted the PMB process for use on shipping containers, ground equipment, trucks, trailers, and various components. Since there is much less concern about the fatigue life reduction possibilities, these non-aircraft applications may use more aggressive media, such as type III and type II, to the best effect. A list of maintenance depots using PMB is in Appendix II. The depots are listed by commodity and product.

1.1.4 The PMB process is not the panacea for all paint removal problems. Limitations on material type and thickness apply to aerospace hardware. To avoid media intrusion problems, the structure must be masked, thus all of the paint cannot be removed by blasting. The plastic media dust/paint chip waste stream may be considered a leachable and hazardous waste, depending on the constituents of the paint and primers being removed and contaminating the waste media. The paint waste may require proper disposal methods as specified in Environmental Protection Agency (EPA) and Department of Transportation (DOT) regulations. If the waste media is nonhazardous, it still presents a large waste volume to dispose of. With all its faults, the PMB process still is the most effective nonchemical coating removal system currently in use for aircraft. It has the widest application at field and depot level maintenance activities, and commercial and military facilities.

1.2 DEFINITION OF ABRASIVE MEDIA BLASTING

Abrasive media blasting is a method of stripping paint, cleaning, and surface roughening by a forcibly projected stream of sharp angular abrasive particles, either dry or suspended in a liquid, against the surfaces of parts or products. Abrasive blast cleaning removes coatings and contaminants and conditions the surface for subsequent finishing.

1.3 DEFINITION OF PLASTIC MEDIA BLASTING

Plastic beads are propelled through specially designed and configured PMB equipment to provide a mild abrasive action during blasting. Plastic abrasive, such as polyester, urea and melamine formaldehyde, acrylic, and polycarbonate, remove surface coatings from metallic and composite substrates. The plastic abrasive also deflash thermoset plastic parts and metal castings and deburr finished machine parts.

1.4 HISTORY OF PLASTIC MEDIA BLASTING

1.4.1 In the early 1980s several aerospace organizations started to evaluate the use of plastic abrasive for removing surface coatings from component parts and airframes. In 1981 the Navy requested proposals for alternative paint removal methods, including abrasive blasting, dry ice, waterjets, and other processes considered less hazardous than the chemical strippers in use at the time. During this time, personnel at NADEP Pensacola, FL, were evaluating PMB as a means of depainting helicopters and components. In 1983 Hill AFB initiated productivity, reliability, availability, and maintainability project number OO-143 to validate a PMB process acceptability for depainting the F-4 Phantom aircraft. Early tests at the engineering, metallurgical, and chemical laboratories at Hill AFB were so encouraging that the Air Force personnel predicted enormous savings in dollars and labor in favor of adopting the PMB process. In 1985 a project to build the first PMB blast booth for airframes was approved and Hill AFB engineers announced the intention to patent and license the PMB process for aircraft stripping. (the process has already been patented in 1947 by DuPont Co.) Nonetheless, PMB attracted great attention and imitation in the aircraft paint stripping industry. The commercial firm (US Technology) that had originally furnished Hill AFB with the detritus of polyester and melamine buttons, profited from being the first in line and, with its General Services Administration (GSA) contract, sold large quantities of media to the Air Force. Other firms were quick to jump on the bandwagon, and soon, there was competition and a pervasive and growing use of the PMB process by military and commercial paint stripping facilities.

1.4.2 The initial joy of replacing hazardous chemical paint stripping methods with a more efficient and less expensive PMB system was short lived. Test results from various organizations indicated some potential drawbacks and undesirable effects on material. Furthermore, an early commercial PMB operator, using an untrained and semiskilled blasting crew, burned holes through portions of an aircraft skin. Similar problems appeared when blast operators gouged divots in composite materials, while using poor blasting techniques and aggressive blasting parameters. Long-term, in-depth testing was indicated for the PMB process to develop suitable blasting parameters, blast equipment, and training programs. Since the new "soft blast" process had used modified sand blasting methods and equipment, new requirements were generated as users gained experience and identified their concerns. Blast machines, media delivery systems, hoses, nozzles, protective clothing, and a reasonably cheap source of soft blasting media were developed.

1.5 APPLICATIONS FOR PLASTIC MEDIA BLASTING

1.5.1 Plastic media can be used to remove any coating found on air and ground vehicles. Elastomeric or rubbery coatings are abrasion resistant, but removable. The soft nature of the blasting media allows the media to chip the paint from the surface without causing severe abrasion. Steel and metals harder than the plastic media are impervious to the blast effects. Plastic and fiberglass components can be treated delicately by using lower pressures and gentle blast techniques to effectively remove paint without gouging resin or fibers. Improvements in blast media characteristics, blast equipment, and blast nozzles will allow improved efficiency, more control in layer-by-layer paint removal, and less peening effect on the substrate surface.

1.5.2 Each blasting application requires a dedicated blasting environment. This is provided by housing the process within a glove box, walk-in blast booth, temporary enclosures for blast rooms within a facility, or a complete blasting facility. For general use the PMB process has found widespread acceptance on a large variety of non-robust metallic and composite substrates as a reasonably fast and economic process. For aerospace hardware, specially designed equipment and facilities have been built at all the Services' maintenance depots. However, there is concern over inappropriate use of general blast equipment and the strict process parameter controls required. Field maintenance organizations are installing PMB facilities to strip airframe components and various noncritical materiel, such as ground support equipment, vehicles, shipping containers, munitions, etc.

1.6 STATE OF THE ART

1.6.1 The Air Force Corrosion Control Board has accepted PMB as an alternative to mechanical or chemical paint stripping methods. General authorization is outlined in technical order (T.O.) 1-1-8, "Application of Organic Coatings," which explains how to apply the process on metal and composite aircraft structures. The minimum thickness of aluminum panels allowed to be blasted with type V media is 0.016". Stripping is also authorized on ground support equipment. General authorization for use must be followed by specific permission granted by the aircraft system manager through the weapon system specific technical data. Aircraft specific paint stripping parameters are outlined in appropriate work control documents and aircraft peculiar technical manuals and specifications.

1.6.2 The Navy has authorized the use of PMB on metals only to include aluminum structures of 0.016" or thicker. Use on structural composite materials has not been authorized since the structural effects testing is not complete. Results of the Navy's evaluation are expected by the end of 1993.

1.6.3 Concerns over the fatigue life degradation due to PMB effects have been a major area of study. When stripping thick aluminum skins (0.060" and greater) the blast stream peening effects have been small and have caused minimal concern for fatigue life degradation, crack growth rate increase, or static mechanical property degradation. However, thin skinned aluminum structures (0.032" thickness and below) have demonstrated susceptibility to PMB-induced mechanical property degradation. Heavy particle contamination (sand or grit) in the PMB stream is the major contributor to fatigue initiation sites and faster crack growth rates are promoted by PMB-induced residual stresses in the thin aluminum structures. Blasting parameters have been developed that minimize the peening effects on thin material. This is witnessed by use of 2024-T3 0.032"-thick non-clad aluminum "Aero-Almen" strips subjected to production representative blasting cycles. Use of these Aero-Almen strips allow measurement of the blast stream peening effects, and comparison between process blasting parameters, media, and techniques. The Almen strips also allow users to develop optimum stripping rates without risking unacceptable blast effects on structures in a production environment.

1.6.4 Composite materials, like thin skinned aluminum, is sensitive to PMB effects. There is concern that the blast media will contribute to interlaminar separation, delamination, and matrix resin cracking. Studies indicate that the PMB process only affect surfaces. Test samples subjected to the most aggressive blasting parameters authorized in T.O. 1-1-8 have not resulted in delaminations, matrix cracking, or separation between matrix resin and structural fibers. However, soft resin is easily removed from surfaces. To avoid problems during the PMB process, is to maintain process control sensitivity and to apply "soft" blast parameters. Formal training is required for operators and they must demonstrate their skill before performing production operations. The rule on composites is that as long as the blasting process is controllable to the point where blast media does not erode through the resin and cause fiber damage, the process is acceptable. Fiberglass materials often use polyester resins as the matrix material, therefore, the blast media and the paint system are made of harder material. In this case the ability to control the process and remove all of the topcoat without eroding some of the surface resin becomes more difficult. Thus, more resin must be applied to the surface before repainting. Experienced operators mask sensitive areas so abrasive sanding can be used during post blasting touch-ups.

SECTION II - MATERIAL, EQUIPMENT AND FACILITIES

2.1 GENERAL

2.1.1 The plastic media blasting (PMB) business has developed from prior experience in the abrasive blasting industry. PMB equipment, materials, and facilities are similar to older blasting equipment and blast rooms. They have been modified to provide more uniform flow of media, better mass flow rate adjustments, better pressure control, and a tighter control on contamination from foreign object debris when the media is recycled through the system. The PMB industry is maturing rapidly. Competition among manufacturers entering the business has resulted in improved equipment and processes and faster stripping with equal or less damage to substrates.

2.1.2 Blasting systems tailored for plastic media are not generally effective with alternative media, such as agricultural grits or hard abrasives, and the converse is also true. Because of the density and flow characteristics of plastic media, the entire system, including the feed hopper, media flow control valve, hoses, nozzles, recovery system, and media separation and recycling system should be designed for use with plastic media. For efficient and reliable operation, the design of the dust separation and media recycling system, is particularly important. This equipment must be designed to separate large and fine particles of paint, as well as fine particles of media and any foreign matter, cleanly from the reusable media. When the type of plastic media is changed, the dust and heavy particle separation equipment must be readjusted to account for the change in media density. The air flow system in the blasting room also must be designed to ensure adequate dust removal, proper visibility, and low concentrations of fine combustible residue so the explosion hazard for media stays well below the lean explosive limit, both in the blast room and the bag house.

2.1.3 Small-scale blast units that can be used in a blasting cabinet, in the open, within temporary enclosures, such as plastic film walls, or within a permanent structure, have capacities of 50 to 250 pounds of media in the feed hopper. Some units have vacuum pickup systems that can draw the media from the floor through a coarse screen to remove large paint particles and then through a tunable hopper. These self-contained units, which are efficient and useful for production, have been used effectively for tests and demonstrations on different types of material and for field stripping components, ground equipment, vehicles, and other material. Some of these small-scale portable units also provide for a closed circuit operation where the blast nozzle is surrounded by a vacuum tube with a larger diameter. When the media comes out of the nozzle, it impacts the surface and gets drawn back, along with the removed paint, through the vacuum system into a separator. The disadvantage of this type of unit is that the vacuum tube hides the point of impingement on the surface being stripped from the operator's view.

2.1.4 Adaptive nozzle systems make blasting inside of tubes or constricted areas possible. Conical, flat, and pinpoint spray patterns are possible using special blasting attachments to modify the blast pattern. Other innovations include portable dust collectors that draw dust particles into a cartridge filter and remote control systems that allow the blast operator to change the media flow and pressure by finger tip control at the nozzle or by a foot control mechanism used in conjunction with a cabinet system.

2.1.5 PMB booths and facilities use upscale equipment sized for multiple blast hoses, higher media flow rates, and longer duty cycles. The main concern of the engineers who design air flow systems is the requirement to provide air velocity of 50 to 75 cubic feet per minute inside the blast room. The media transport, delivery, recovery, and reclamation systems all are similar, but are designed to accommodate multiple blast hoses and large bulk media flow rates. A facility design scheme is made to support the 150 - 175 cubic feet per minute blasting air requirement per blast hose in the booth. Media feed points and reclamation designs permit addition of fresh media as old media is broken down and discarded during the blasting process. Reclaim systems must account for batch processing the media as it is swept up from the floor into reclaim transport chutes. Appropriate ventilation systems not only must provide the required mass of air flow, but also try to suck airborne media into the ventilator shafts, causing high media consumption rates and requiring concern for media clean out requirements in the vent system. Since PMB creates so much static electricity, provisions must be made to account for possible sparking around volatile fluids or gases and for explosive concentrations of gas or dust. The provisions include defueling and grounding aircraft, grounding blast hoses, and blasting substrates that spark, such as titanium, before the dust concentrations rise in the blast room. Other facility interfaces must account for personnel safety, such as oil free breathing air, good lighting, alarm systems, safety monitors, and safety interlock systems that prevent operation when the critical ventilation or air flow systems are down.

2.2 PLASTIC MEDIA MATERIAL

2.2.1 MIL-P-85891 Description of Plastic Media Material.

2.2.1.1 The media finished product shall be made from chlorine-free stock of polyester (type I), urea formaldehyde (type II), melamine formaldehyde (type III), phenol formaldehyde (type IV), acrylic plastic (type V), or poly, allyl glycol carbonate (type VI), by processing to the desired size distribution specified within MIL-P-85891. The finished product shall be magnetically cleaned prior to shipment. The finished product shall contain no inorganic fillers. It may contain anti-static agents. The odor of the finished product shall not be objectionable during actual use.

2.2.1.2 Types I through IV and type VI shall not produce a surface residue that interferes with the application of MIL-C-81706 aluminum chromate conversion coating. Blast residues from type V shall be removable with methyl ethyl ketone.

2.2.1.3 The finished product shall not cling to the interior walls of a well grounded blast booth or glove box during the stripping test.

2.2.1.4 The plastic media covered by MIL-P-85891 are abrasive blasting material for paint removal. The visual appearance of surfaces stripped using this media can vary from no discernible effect to extensive erosion damage. Other damage may occur, which is not visually apparent, but which may be manifested as loss of fatigue life. Those effects depend on the nature of the substrate, type of plastic media used, and the contamination of recycled media, nozzle pressure, angle of impingement, and distance of the blast nozzle from the work. Before using these media for production blasting, appropriate engineering studies shall be initiated to determine the effects of the process and the media on the substrate. Surface residue, which can result from the use of any plastic media, should be removed before to refinishing. Type V residues must be removed using methyl

ethyl ketone or similar solvent. Types I, II, III, IV, and VI residues can be removed using a detergent wash.

2.2.1.5 Barcol hardness of plastic stock, before crushing, shall be within the following limits, when tested as specified in MIL-P-85891. Barcol hardness is determined in accordance with (IAW) the American Society for Testing and Materials (ASTM) D 2583 by means of a Barcol impresser. (The approximate Moh hardness is included for information only.)

Type	Barcol Hardness	Approximate Moh Hardness
I	34 TO 42	3.0
II	54 TO 62	3.5
III	64 TO 72	4.0
IV	54 TO 62	3.5
V	46 TO 54	3.5
VI	30 TO 40	3.0

2.2.1.6 Dyes or pigments shall be allowed for coloring and shall be blended into the resin before curing. Where uniform colors are specified, the following color codes shall be used (all colors shall be IAW MIL-STD-104):

Type I	light blue
Type II	light yellow
Type III	light pink
Type IV	dark brown
Type V & VI	white or light grey

2.2.1.7 The media finished product shall be manufactured from selected plastic stock of the exact chemical type required by the specification. Grade A finished product shall be manufactured from virgin plastic stock (material in the form of unprocessed sheet or block made specifically to produce plastic media); Grade B plastic stock shall be scrap plastic (material produced as a by-product of manufactured plastic items such as shirt buttons, dinnerware, etc.). Mixing different types of plastics shall not be permitted.

2.2.1.8 The media finished product shall not be an explosive or ignitable.

2.2.1.9 The media finished product shall not adversely affect the health of those who use it properly. Material safety data sheets for the dyes or pigments used in the media, and for any material added to the media (such as anti-static agents) shall be prepared and submitted IAW FED-STD-313, one copy of which shall accompany the sample being submitted for first article inspection.

2.2.1.10 The physical and chemical properties of the media finished product shall be IAW Table I:

TABLE I

PHYSICAL AND CHEMICAL PROPERTIES

PROPERTY	REQUIREMENT BY TYPE						MIL-P-85891 TEST
	I	II	III	IV	V	VI	Paragraph
Chlorine content, Max (% by weight)	trace	trace	trace	trace	trace	trace	4.5.4
Ash content, max %							4.5.5
Grade A	0.5	0.5	0.5	0.5	0.5	0.5	
Grade B	2.0	2.0	2.0	2.0	2.0	2.0	
Iron content, max %	0.05	0.05	0.05	0.05	0.05	0.05	4.5.5.1
Specific Gravity							4.5.6
Minimum	1.15	1.47	1.47	1.47	1.10	1.28	
Maximum	1.25	1.52	1.52	1.52	1.20	1.33	
Extract content, max (% by wt.)	5.0	1.0	1.0	1.0	1.0	1.0	4.5.7
pH of water extract							4.5.8
Minimum	4	4	4	4	4	4	
Maximum	8	8	8	8	8	8	
Conductivity, max (Mho/cm)	100	100	100	100	100	100	4.5.8
Water absorption, max (% by wt.)	2.0	10.0	10.0	10.0	2.0	2.0	4.5.9
Heavy particles, max (% by wt.)	0.02	0.02	0.02	0.02	0.02	0.02	4.5.10
Light particles, max (% by wt.)	0.1	1.0	1.0	1.0	0.1	0.1	4.5.10

2.2.1.11 The media finished product shall have a particle size distribution as shown in Table II:

2.2.1.12 The media finished product shall conform to the performance property requirements of Table III and the surface residue and anti-static behavior requirements, when tested using a finished product that conforms to the 20-30 particle size distribution. Other sizes of the finished product shall be manufactured from the same plastic stock and shall differ only in size distribution resulting from the manufacturer's screening operation. Blasting parameters and requirements shall be as specified in Table III:

2.2.2 Filled Plastic Materials.

2.2.2.1 Urea Formaldehyde (Type II).

2.2.2.1.1 Description. Urea formaldehyde is a thermosetting amino resin formed by the controlled reaction of formaldehyde with various compounds that contain the amino group NH_2. Urea formaldehyde is supplied as a liquid, as a spray dried solid, and as a filled molding compound. Applying heat to the presence of acid catalysts converts these materials into hard infusible products. The urea currently being used as a plastic media for coatings removal is manufactured from urea molding compounds. Alpha cellulose filled urea molding compounds are used for type II blasting media, which is manufactured by a number of companies. Alpha cellulose filled urea molding compounds also are used to manufacture wiring device parts (circuit breakers, wall plates, receptacles), closures for bottle tops, electric blanket control housings, toothpaste tube inserts, buttons, etc.

2.2.2.1.2 Material Characteristics.

General

MIL-P-85891 identification	- Type II
Melting Temperature	- N/A (thermoset)
Tensile Strength	- 5,500 - 13,000 psi
Compressive Strength	-25,000 - 45,000 psi
Hardness	- Rockwell M 110-120
Specific Gravity	- 1.47 - 1.53

Specific To Coating Removal

Hardness	- Barcol 54-62 (Moh 3.5)
Ash Content, Max	- 0.5% (must not contain mineral fibers)
Chlorine Content, Max	- Trace (could come from water supply)
Iron Content, Max	- 0.05% (colorant related)
pH of Water Extract	- 4 - 8 (should be neutral)
Bulk Density	- 58 - 60 lbs/cu ft
Substrate Temperature, Max	- 350 degrees F
Ignition Temperature	- 530 degrees F*
Explosibility	- 0.085 oz/cu ft*

*From Composition Materials Co., Inc., Technical Data Sheet.

2.2.2.1.3 General Performance Characteristics.

2.2.2.1.3.1 Urea formaldehyde was one of the plastic materials initially evaluated at Hill AFB, UT, during the early 1980s. It rapidly became the material of choice for use on the F-4 because of the F-4 structure and performance economics. The F-4 has very little soft or thin sheet aluminum and composites.

2.2.2.1.3.2 At 54-62 on the Barcol hardness scale, type II media is soft enough to have a minimal surface distortion effect on 7075-T6 under normal blasting conditions of 30-40 pounds per square inch (psi) and 18-24 inch standoff distance. On 2024-T3 there is a more pronounced effect with surface distortion (peening effect) visible under 30 power magnification. The intensity on 2024-T3 Almen strips ranges from 2 to 10 mils, depending on the blast pressure, angle, and distance. Also, the peening effect on 6061 aluminum is more pronounced with extended blasting resulting in a uniformly distorted surface.

2.2.2.1.3.3 Type II media is urea formaldehyde held together by alpha cellulose filler, which actually behaves as a copolymer in abrasive blast particles. Because of the alpha cellulose, the media particles are block shaped with very rough surfaces. The media's rough surfaces cause coating systems to abrade, while the more angular corners of the particles "chip" away the coating. Type II media is harder than most composite resins, therefore, care must be taken when blasting composites not to go below the primer layer.

2.2.2.1.3.4 Blasting with type II media creates a fair amount of dust. This means the blast room must have good cross ventilation. Also, there are potential static problems that can be minimized by properly grounding the blast equipment and work piece. Manufacturers incorporate an anti-static agent in virgin media. Dust collecting systems, however, will remove the anti-static agent in ground reclaimed media.

2.2.2.1.4 General Applications. Urea formaldehyde has emerged as the all purpose "work horse" plastic media. Applications for urea formaldehyde include, but are not limited to, the following:

1. Aircraft skin coatings removal. Approvals and applications are specific to the original equipment manufacturer and the specific airframe/weapon system. In general, type II media has been used on thicker clad commercial aircraft skins and on other harder aircraft alloys.

2. Aircraft structural components such as landing gear, wheels, and other thick structural components requiring coating/contaminant removal.

3. Coatings and sealant removal from ground support equipment in the aircraft industry and from non-aircraft such as aluminum boats, automotive ground vehicles fiberglass boats, sheet metal structures, and hardwood furniture.

4. Contaminant removal in general, such as ash residue from bake-off, carbon removal from engine parts, oxidation on brass/copper/decorative parts, and removal of investment casting residue.

5. Industrial cleaning of tools, rubber/plastic molds, paper manufacturing tooling, resin removal from composites manufacturing tools, spray paint systems, baking equipment, and die cast molds (zinc/aluminum).

6. Surface preparation applications such as core defining in sand casting, deburring soft metals/plastics/ceramics, deflashing die cast metals/molded thermoset plastic, etching printed circuit boards, pre-laminate roughening of composites/plastics, removing heat treated scale from soft metals, removing resin bleed from electronic parts, and preparing plastics before finishing.

2.2.2.1.5 Special Equipment Issues.

2.2.2.1.5.1 Urea formaldehyde can be used in any direct pressure blast system with minor modifications to ensure media flow. For surface critical applications, the system should be dedicated to plastic media. Additionally, for critical applications, the recycling system should have a set of screens to make sure oversized particles get removed and dense particle separators should be incorporated to help remove heavy/hard particles within the working mix size range.

2.2.2.1.5.2 Urea formaldehyde media can be used in suction blast equipment, but controlling the media flow is more difficult. For non-surface critical high-volume applications, suction equipment may be preferred since it allows continuous blasting. The type II media also can be used in turbine wheel/centrifugal blasting systems. The wheel speed must be reduced and the wheel blades must be specially coated to minimize breakage when media comes in contact with the blades. For direct blast equipment a variable metering orifice is preferred, because operators can easily adjust the mass flow without changing blast pressure at the nozzle. Grounding the blast equipment and the work piece minimizes static dust buildup during operation.

2.2.2.2 Melamine Formaldehyde (TypeIII).

2.2.2.2.1 Description. Melamine formaldehyde, like urea formaldehyde, is an amino resin formed by the controlled reaction of formaldehyde with various compounds that contain the amino group NH_2. The greatest difference between the two is that there is a larger amount of chemical cross linking with melamine. Because of the additional cross linking, a more stable resin results. Melamine is harder than urea and resists higher temperatures. In general, thicker parts are molded from melamine since higher temperatures and pressures are used, however, the basic manufacturing process is the same for cellulose filled molded melamine parts as it is for urea.

2.2.2.2.2 Material Characteristics.

General

MIL-P-85891 identification	- Type III
Melting Temperature	- N/A (thermoset)
Tensile Strength	- 5,000-13,000 psi
Compressive Strength	- 33,000-45,000 psi
Hardness	- Rockwell M 115-125
Specific Gravity	- 1.47-1.52

Specific To Coating Removal

Hardness	-	Barcol 64-72 (Moh 4.0)
Ash Content, Max	-	0.5% virgin, 2.0% recycled
Chlorine Content, Max	-	N/A
Iron Content, Max	-	0.05% (related to colorants)
pH of Water Extract	-	4-8 (should be neutral)
Bulk Density	-	58-60 lbs/cu ft
Substrate Temperature, Max	-	400F degrees
Ignition Temperature	-	>530F degrees*
Explosibility	-	0.09 oz/cu ft*

*From Composition Materials Co., Technical Data Sheet

2.2.2.2.3 General Performance Characteristics.

2.2.2.2.3.1 An additional increment of hardness associated with cross linking polymers is the basic difference between urea and melamine. Also, because of the cross linking, melamine is stable at slightly higher temperatures. One can see the difference in hardness on blasted surfaces and analyzing arc height data. Melamine, type III, is more friable and is dustier when it breaks down in the blasting process. As with urea, an anti-static agent is incorporated by most manufacturers of melamine blast media. Like type II media, type III requires good cross ventilation in a blast room. Because of its hardness, type III has become more of a specialty material for use on harder substrates.

2.2.2.2.3.2 Arc heights as high as 14 mils for type III versus a maximum of 10 mils for type II were observed in Battelle data on arc heights. It should be noted, however, that at blast pressures as high as the 60 psi used in the Battelle study, the paint removal rate is so fast that excessive dwell time takes place. Using robots to strip paint may allow the use of type III at lower pressure and smaller particle size ranges on certain alloys.

2.2.2.2.3.3 Type III is too hard for use on 6061 aluminum, particularly in some applications involving thick coatings on structural parts. The blast pattern of type III can be seen on 2024-T3 aluminum following a single blast cycle. While type III distorts the surface on 7075-T6 less saturation blasting results in full visual coverage under 30 power magnification.

2.2.2.2.4 General Applications.

2.2.2.2.4.1 Type III media is more operator sensitive than is type II and requires greater control because of its hardness. It has limited use on aircraft fuselage coating removal, however, it has been used at lower pressures and at shallow angles successfully.

2.2.2.2.4.2 Principal applications for melamine formaldehyde are the same as those for urea in the non-aircraft market. Type III has considerable use on ground vehicles such as autos, vans, tractors, and trailers. In addition, the Army uses it to remove coatings from weapon systems and ground personnel carriers.

2.2.2.2.4.3 Type III has an advantage over type II in the tire industry. Molds can be cleaned at a higher operating temperature with type III and thereby minimize the amount of time "off line" while they are being cleaned.

2.2.2.2.5 Special Equipment Issues.

2.2.2.2.5.1 Type III media can be used in any direct pressure blast system with minor modification to ensure media flow. The blast system should be dedicated to plastic media and should include a recycling system that has screens for removing oversized particles along with a dense particle separator for removing heavy/hard particles within the working mix size range. A variable metering orifice is preferred for direct blast equipment, because operators can easily adjust the mass flow without changing blast pressure at the nozzle.

2.2.2.2.5.2 Type III media can be used in suction blast equipment although controlling the media flow is more difficult. For non-surface critical high-volume applications, suction equipment may be preferred since it allows continuous blasting.

2.2.2.2.5.3 Turbine wheel/centrifugal blasting systems can be used. The wheel speed must be reduced and the wheel blades must be specially coated to minimize breakage when media when comes into contact with the wheel blades.

2.2.2.2.5.4 Grounding the blast equipment and the work piece minimizes static dust buildup during blasting. Improved ventilation may also be necessary because of higher dust generation.

2.2.2.3 Phenol Formaldehyde (Type IV).

2.2.2.3.1 Description. Phenolic resin is produced by condensing phenol with formaldehyde in base to form a heat-cured thermoset material with a chemical structure that is highly cross linked. The phenol formaldehyde included in MIL-P-85891 is presumed to be the cellulose filled formula and since most available resins are filled with glass or other materials type IV media is not being used in any quantity in PMB. Phenolic resins are used in general purpose molding compounds and in high performance engineering grade materials. General purpose compounds incorporate fillers, reinforcements, and phenolic resin. The fillers may include mica, clay, wood flour, cellulose, mineral fibers, and chopped fabric. They are sold to the molder in a ready-to-be-molded state with the filler incorporated. General purpose phenolics are used in high-temperature electrical products, such as oven and toasters, ashtrays, wiring devices, switch gears, pulleys, and pot handles. Engineered phenolics are used in automotive applications, such as water pumps, brake pistons, and electrical connectors.

2.2.2.3.2 Material Characteristics.

General

MIL-P-85891 identification	- Type IV
Melting Temperature	- N/A (thermoset)
Tensile Strength	- 3500-6500 psi
Compressive Strength	- 22000-31000 psi
Hardness	- Rockwell M 95-115
Specific Gravity	- 1.38-1.42

Specific to Coatings Removal

Hardness	- Barcol 54-62 (Moh 3.2-3.5)
Ash Content, Max	- 0.5% virgin, 2.0% recycled
Chlorine Content, Max	- Trace
Iron Content, Max	- 0.05% (related to colorants)
pH of Water Extract	- 4-8 (should be neutral)
Bulk Density	- N/A
Substrate Temperature, Max	- N/A
Ignition Temperature	- 390F degrees*
Explosibility	- 0.079 oz/cu ft*

*From Composition Materials Co., Inc., Technical Data Sheet

2.2.2.3.3 General Performance Characteristics. No technical data base exists on the phenol formaldehyde plastic blast media (type IV) in the MIL-Specification. That probably is because some manufacturers in the early days of PMB mixed phenolics with other resins in the manufacturing process.

2.2.2.3.4 General Applications. Cellulose filled phenol formaldehyde form should serve the same applications as urea and melamine.

2.2.2.3.5 Special Equipment Issues. None.

2.2.2.3.6 Other Issues. Operators must be careful when using type IV media to depaint aircraft, unless the material has been specifically formulated for the application. Glass and mineral filled products, for example, have a higher density and hardness, which can cause substrate damage. Operators also must avoid using asbestos filled phenolic in blasting for the obvious health hazards. In addition, cotton and wood flour filled phenolics could cause excessive dust during blasting.

2.2.3 Unfilled Plastic Materials.

2.2.3.1 Polyester-Rigid Cast Thermoset (Type I).

2.2.3.1.1 Description. Thermoset polyester curing differs from urea, melamine, and phenol in that it is cooked and cured in cast sheet form, while urea, melamine, and phenol are cured under temperature and pressure. The final resin performance for polyester is determined by the type of starting material, manufacturing process controls, and cooking temperature. Pure cast sheet products make up a small percentage of the total polyester market as they are generally used in combination with fillers and reinforcers, such as fiberglass. The button industry is the major user of unfilled cast sheet polyester. Beginning with "button holes," PMB blast media expanded to chopping/grinding off specification buttons and, finally, to making cast sheet polyester. Another major consumer is the construction market which uses polyester resin to manufacture cultured marble and onyx, sanitary ware, glass fiber reinforced tub and shower units, building facades, specialty flooring material, and decorative elements. Additionally, the transportation industry uses polyester to make sheet molding compound has been replacing metal parts.

2.2.3.1.2 Material Characteristics.

General

MIL-P-85891 identification	-	Type I
Melting Temperature	-	N/A (thermoset)
Tensile Strength	-	600-13000 psi
Compression Strength	-	13000-30000 psi
Hardness	-	Barcol 35-75
Specific Gravity	-	1.04-1.46

Specific to Coatings Removal

Hardness	-	Barcol 34-42 (Moh 3.0) (low end of above)
Ash Content, Max	-	0.5% virgin, 2.0% recycled
Chlorine Content, Max	-	Trace
Iron Content, Max	-	.05% (colorant related)
pH of Water Extract	-	4-8 (should be neutral)
Bulk Density	-	45-48 lbs/cu ft
Substrate Temperature	-	250F degrees
Ignition Temperature	-	N/A
Explosibility	-	N/A

2.2.3.1.3 General Performance Characteristics. The polyester cast sheet product used in PMB is unfilled and forms sharp points and flat surfaces when it is chopped into blast particles. This makes it behave differently from urea, melamine, and phenol formaldehyde media. Polyester (type I in MIL-P-85891) causes very low residual stress in 2024-T3 and 7075-T6 aluminum, even when blasted at pressures as high as 50-60 psi, and softer polyester removes aircraft coatings slowly. In general the polyester blast particles work by using their sharp edges to chip away at coatings and contaminants. Unlike amino thermoset, polyester does not abrade coatings. Because of polyester's low density and angular shape it is more difficult to get the material to flow uniformly in a blast system. Where an anti-static agent is desirable with urea and melamine, it is necessary with polyester. Because polyester is unfilled and soft, it absorbs energy when it impacts a harder substrate. Therefore, if a coating system is well adhered and harder than the polyester, the coating will withstand the blasting process. While urea and melamine abrade and cause dust during blasting, polyester stays in tact until it reaches a critical energy absorption level. At that point, the unfilled polyester shatters into a number of very small fragments.

2.2.3.1.4 General Applications. Polyester can be used in many of the applications served by urea and melamine, however it is not "performance competitive " in most processes. If urea is the general purpose material and melamine is the aggressive material, thermoset polyester can best be described as the most delicate of the thermoset plastic blast media. As such, polyester can be used to remove resin bleed from electronic parts and to deflash of molded thermoset plastic. Polyester can be used to blast fiberglass and composites as long as the gel coat is undisturbed.

2.2.3.1.5 Special Equipment Issues. Low density polyester has difficulty flowing freely and evenly in the blast system. Since the material tends to "bridge," and increased aeration of the pressure vessel may be required. For critical substrate applications, where high operating pressures are required to remove well adhered coatings, heavy/hard particle separator equipment is very important. Also, because polyester has a lower explosibility threshold than urea and melamine, the work area must be adequately ventilated to minimize dust.

2.2.3.1.6 Other Issues. If type I media is to be used in a critical application, it must be made from unfilled cast sheet polyester. More than 95% of polyester products are filled with fiberglass or mineral fillers, which are hard enough to damage thin sheet soft aluminum alloys.

2.2.3.2 Acrylic (Type V).

2.2.3.2.1 Description.

2.2.3.2.1.1 Most acrylics begin with a methyl methacrylate monomer that is polymerized by a free radical process, the addition of peroxide. Acrylics can be cast in sheets, rods, or tubes. Sheet acrylic, which is still used to make aircraft canopies and windows, is polymerized between glass plates through an exothermic reaction that must be closely controlled to prevent voids in the finished product. Known for their clarity and surface hardness, acrylics have good weatherability, light transmission, chemical resistance, and toughness.

2.2.3.2.1.2 Acrylic plastic media is manufactured from cast or extruded sheet by cryogenic grinding. The grinding process used to manufacture thermoset plastic abrasive creates too much heat for thermoplastic acrylics.

2.2.3.2.1.3 Acrylics are modified with various ingredients to increase impact strength and, in some cases, to alter the refractive index used to match other materials in transparency. It can be purchased in bead or pellet form for extrusion, injection, or compression molding. Extruded sheet acrylic is available in a variety of thicknesses from 0.048 inch to 0.25 inch. Extruded sheet and cast sheet acrylics are roughly equivalent in cost in the thicker sizes. Sheets can be cut with power saws and thinner sheet can be scribed and broken like glass. Injection molding can be accomplished on any conventional injection molding machine, however higher pressures are required as the material is fairly viscous. Highly polished chrome plated molds normally are used to ensure a good surface finish. Acrylic molding compounds are used broadly in the automotive industry for tail lights, side markers, instrument covers, nameplates and dials. They also are used to make signs because of excellent weatherability.

2.2.3.2.2 Material Characteristics.

General

MIL-P-85891 identification	- Type V
Melting Temperature	- 194-221F degrees
Tensile Strength	- 8000-11000 psi
Compressive Strength	- 11000-19000 psi
Hardness	- Rockwell M 80-100
Specific Gravity	- 1.17-1.20

Specific To Coatings Removal

Hardness	- Barcol 46-54 (Moh 3.5)
Ash Content, Max	- 0.5% virgin, 2.0% recycled

Chlorine Content, Max	- Trace
Iron Content, Max	- 0.05%
pH of Water Extract	- 4-8 (should be neutral)
Bulk Density	- 45-48 lbs/cu ft
Substrate Temperature, Max	- 200F degrees
Ignition Temperature	- 734F degrees*
Explosibility	- 0.079 oz/cu ft*

*From Composition Materials Co., Inc., Technical Data Sheet.

2.2.3.2.3 General Performance Characteristics. Acrylic, type V, has emerged as the best available plastic media for stripping coatings from thin, soft aluminum alloys. The blast particles are very angular, like polyester, but have a harder surface with a density equal to or lower than polyester. Type V fills the void between polyester and urea. Polyester is not aggressive enough to achieve acceptable strip rates, while urea is considered too aggressive for certain thin sheet aluminum and composite applications. An anti-static/flow agent definitely is required for type V media. Because of its low density, acrylic media tends to bridge in the blast system and clump in the presence of moisture.

2.2.3.2.4 General Applications. Acrylic media can be used on any thin sheet, soft alloy with a coating that must be removed. It can be used for deburring soft metals, plastics, and ceramics; deflashing die cast metals and molded thermoset plastic parts; and, removing resin bleed from electronic parts. Applications include aircraft components made of aluminum, magnesium, and composites; aluminum boats; on automotive wheels, composites, fiberglass structures; and, ground vehicles with fiberglass/composite bodies.

2.2.3.2.5 Special Equipment Issues. Because the density and particle geometry of acrylic blasting material may cause it to bridge in the blasting system, anti-static and flow agents are required and, to lessen static attraction, the equipment and work-piece should be grounded.

2.2.3.2.6 Other Issues. Concerns exist about residual smear left by blasting with thermoplastic media, which may result from using an anti-static agent as a topical or recycled acrylic. After depainting an aircraft, the surface is subjected to follow-on operations that remove the smear.

2.2.3.3 Allyl Diglycol Carbonate (Type VI).

2.2.3.3.1 Description.

2.2.3.3.1.1 Allyl esters are available as low viscosity monomers and thermoplastic prepolymers. Allyls are used as cross linking agents for unsaturated polyesters and for preparing reinforced thermoset molding compounds and high-performance transparent parts. Allyl resins have good electrical properties in high temperatures and humidity. Molded parts have dimensional stability, chemical resistance, mechanical strength, and good heat resistance. Allyls are used primarily in molding compounds and in pre-impregnated glass, cloth, and paper.

2.2.3.3.1.2 Allyl carbonates, such as the material from which type VI blasting media is manufactured, is used when optical transparency is required. It is the primary material used to manufacture plastic lenses for eye wear because of light weight, dimensional stability, and transparency. Allyl compounds find use in electric connectors, instrument panel covers, camera filters, and a variety of glazing applications in communications, computer,and aerospace systems.

2.2.3.3.2 Material Characteristics.

General

MIL-P-85891 identification	- Type VI
Melting Temperature	- N/A (thermoset)
Tensile Strength	- 5000-6000 psi
Compression Strength	- 21000-23000 psi
Hardness	- Rockwell M 95-100
Specific Gravity	- 1.3-1.4

Specific To Coatings Removal

Hardness	- Barcol 30-40 (Moh 3.0)
Ash Content, Max	- 0.5% virgin, 2.0% recycled
Chlorine Content, Max	- Trace
Iron Content, Max	- 0.05% (should be zero)
pH of Water Extract	- 4-8 (should be neutral)
Bulk Density	- 52-54 lbs/cu ft
Substrate Temperature, Max	- 300F degrees
Ignition Temperature	- 710F degrees*
Explosibility	- N/A

*From Composition Materials Co., Inc., Technical Data Sheet.

2.2.3.3.3 General Performance Characteristics. Like acrylic and thermoset polyester, allyl carbonate is unfilled. When ground into blasting media, it forms particles with very sharp edges. This, and the specific gravity, may account for claims that type VI can be used at lower operating pressures than acrylic. Allyl is between acrylic and urea in density, but overlaps acrylic on the Rockwell M hardness scale. Allyl is the only material of the six types of media in which the Rockwell hardness and the Barcol hardness do not compare in MIL-P-85891; it's Barcol hardness is equivalent to that of polyester, while its Rockwell hardness is at the top end of the acrylic range.

2.2.3.3.4 General Applications. Allyl diglycol carbonate overlaps the applications covered by thermoset polyester and acrylic. It is recommended for blasting composites, aircraft components made of aluminum and magnesium, fuselages, missile skins, and fiberglass structures. Allyl also can be used to strip ground vehicles. Because of its good cutting action and low hardness, it removes decals from sensitive substrates and paint and varnish from hardwood furniture and architectural items.

2.2.3.3.5 Special Equipment Issues. Like acrylic and polyester, allyl blast media requires an anti-static agent to ensure flowability. Designed for use at lower pressures, the equipment must be able to maintain acceptable mass flow rates at pressures in the 20-25 psi range. Avoid pulsing when working on sensitive substrates.

2.2.3.3.6 Other Issues. A better understanding of the material is needed to explain why it works as the manufacturers claim. Also, the issue of hardness needs to be addressed. While the material is soft when ground into blasting media, it forms particles with sharp, glass-like edges. Under magnification, allyl diglycol looks more like glass than plastic media.

2.3 MEDIA DELIVERY SYSTEMS.

2.3.1 Introduction.

2.3.1.1 Plastic media blasting systems are designed to deliver a media with enough air volume to propel it effectively against a target surface. The systems are used for coating removal, cleaning, or surface modification. A variety of PMB systems have been developed with distinct transport and delivery systems designed to provide the best performance for specific applications and media type. The equipment needed to deliver an effective blast stream consists of a media storage vessel, pressurized blasting pot, media metering valve, controls and safety interlock devices, blasting hoses, and blasting nozzles. Manufacturers share a product line that relates to the same fundamental components. However, there is great variety, as particular features and accessories are incorporated, to provide better operator control, continual blasting, multiple blast hoses from the same pressure pot, economical use of media, faster media flow and blast stream stabilization, and many other competitive features.

2.3.1.2 The DOD had tried just about every style and type of blasting equipment and component. The department has compared these systems and components and found that they all work reasonably well. Private industry has developed equipment and processes to effectively remove military coatings from aircraft and other material without damaging them. As a result of this cooperation between industry and the DOD, PMB equipment and process requirements have matured.

2.3.2 Blasting Pots.

2.3.2.1 General. Blast machines come in various sizes to accommodate different abrasive storage capacities. As a rule the smallest machine should hold at least enough media to blast for 30 minutes. The amount of media and air used depends on the size of the nozzle(s) being used and the desired air pressure. To work efficiently, the compressor capacity should exceed the actual requirement. On the chart below, the top number shows the minimum air requirement in standard cubic feet per minute (SCFM) for various nozzles and pressures, and the bottom numbers show pounds of media/hr. Flow rates are approximate since they depend on the grit valve adjustment.

NOZZLE SIZE	POUNDS PER SQUARE INCH							
	25	30	35	40	45	50	60	
1/4	28	32	37	41	45	49	56	SCFM
	(78)	(89)	(103)	(114)	(125)	(136)	(156)	(lbs media/hr)

5/16	44 (122)	50 (139)	57 (158)	64 (178)	70 (194)	76 (211)	88 (244)
3/8	63 (176)	73 (203)	82 (228)	91 (252)	100 (277)	109 (303)	126 (350)
7/16	85 (236)	99 (275)	112 (311)	124 (344)	137 (381)	149 (414)	172 (473)
1/2	112 (311)	129 (353)	146 (406)	163 (453)	179 (497)	194 (539)	225 (625)

References for compressor requirements are for a given consumption. The feed line from the compressor to the blast pot normally is provided through a 1.25-1.5 " diameter pipe that provides the lowest pressure drop.

10 HP	(7.5 KW) =	43 CFM @ 100 PSI
15 HP	(11 KW) =	65 CFM @ 100 PSI
20 HP	(15 KW) =	86 CFM @ 100 PSI
25 HP	(19 KW) =	97 CFM @ 100 PSI
30 HP	(23 KW) =	120 CFM @ 100 PSI
40 HP	(30 KW) =	172-190 CFM @ 100 PSI
50 HP	(38 KW) =	215-235 CFM @ 100 PSI

2.3.2.2 Single Chamber Blasting Pots. Pressure pots are made of steel, are ASME rated, and come in single and dual chamber varieties. Some manufacturers have rounded bottoms on their pots while others use 35- to 60-degree cones to provide better media flow. The typical pot is a round cylinder with a cone shaped bottom. The interior of the pot is often lined with an abrasive resistant coating such as urethane.

2.3.2.3 Dual Chamber Blasting Pots. A dual chamber system is designed for non-stop production blasting. Production continues while the machine is refilling either by an overhead hopper or manually loaded with bagged media. To begin blasting both chambers are filled and pressurized. Media in the upper chamber is transferred to the lower as the media is consumed. When this transfer is complete, the upper chamber is depressurized for refill, while the lower remains under pressure and blasting continues. The upper chamber again is pressurized and, when the lower chamber reaches a specified lowest level as controlled by a sensor, the upper chamber is again vented to the lower chamber. The cycle is continually repeated for non-stop blasting.

2.3.3 Media Flow Valves. Media must be regulated to give consistent blast performance and predictable peening effect. Controlling the degree of a blast system's media flow depends on the method of linear adjustment for media flow. The goal is to change the area of restriction in a linear fashion and to provide a repeatable setting indicator for the operator. Media flow is sensitive to orifice modifications or changes in valve position. A slight adjustment or repositioning of the valve may result in a large change in media flow. The restriction may be as simple as a replaceable orifice plate with different sized holes, which could be adjusted by using a sliding plate over the orifice or force feeding the media by pressure differential through an adjustable valve. Other common flow metering techniques include the pinch valve, where a flexible membrane is pinched to modify the restricted area and augers that drive media from a storage tank into the blast stream to control the media by adjusting the rotational speed of the auger.

2.3.4 Safety Interlocks and Controls. All blast machines are required by OSHA to have a remote control mechanism. Each manufacturer makes a "deadman" switch that physically operates intermittently to close the loop in the air system. Deadman switches must be easy to operate for an operator wearing leather gloves. When the switch is released or the hose dropped, the switch must open and remain open to stop media flow and cut off the air flow. The deadman switch may be connected electrically or pneumatically from the control pressurization valve and the nozzle or end effector.

2.3.5 Blasting Hoses. Traditional sand blasting hose is tough and durable but, because of its size and weight, it is cumbersome and difficult to use with the precise control required for PMB. Newer blast hose is made of synthetic and natural rubber compounds molded into tubular shapes, then reinforced with tough nylon braided material and covered by abrasion resistant material.

2.3.6 Blasting Hose Coupling. Blast hose couplings and nozzle holders are an essential part of the air flow chain. Proper attention must be paid to the fit and mating tolerances to avoid unnecessary and costly air leaks. Hose couplings are made of top grade brass and aluminum in addition to tough nylon materials. Universal quarter-turn locking lugs allow interconnecting size hose couplings from 1/2 inch to 1-1/2 inches. Coupling shanks are extra long for added support and holding strength. Nylon couplings have the added feature of a steel safety spring that automatically engages into two sets of holes in the coupling flanges to add back-up security. Safety wire must be added to brass and aluminum couplings to prevent accidental uncoupling. Also, there are two basic methods of attaching nozzle holders to the blast hose. One method incorporates internal spring grip rings, which bite into the hose when the hose expands under pressure. The other method of nozzle attachment uses the quick coupling configuration of a universal quarter turn locking lug and attaches directly to the hose.

2.3.7 Blasting Nozzles.

2.3.7.1 Blasting nozzles, which come in a great variety, can be selected for extra control sensitivity, increased strip rate, or special applications. Early in the development of sand blasting processes workers found that worn nozzles were more effective than new ones. This discovery led to the development of new designs. Today nozzles are engineered to give different blast-stream shapes, from round ones to thin rectangular footprints. Based on the media type and size, a blast nozzle can be engineered to provide fast or slow traverse speeds, narrow or wide stripping swaths, coarse or fine control sensitivity, or maximum operator utility for specific tasks. Desired changes in a production blasting process may be needed to increase strip rates, decrease damage, or to accommodate new production variables, such as a change in media type. The single factor offering the best opportunity for development to satisfy a need to work faster, cheaper, or smarter is nozzle design.

2.3.7.2 The size of the nozzle orifice is the single most critical factor in correctly selecting a blast nozzle. Orifice diameter determines how much abrasive will be consumed and how much air pressure and volume are needed. Currently, most blasting nozzles in use are operated with enough pressure to make the air stream go supersonic in the divergent section of the nozzle. Venture type nozzles increase the velocity of blast media as it exits the nozzle throat and enters the expanding supersonic section of the nozzle. The area ratio for straight and common venture nozzles having a round cross-section is 1.0 to 2.25 inches respectively. As the area ratio increases, the velocity of air increases and drags the abrasive particles along imparting higher velocities. As the area ratio increases, the pressure drop across the nozzle throat increases. This requires a change in air flow pressure to maintain equivalent pressure at the nozzle inlet. Since the airstream has a given amount of energy based on the CFM of airflow, the point of maximum velocity pickup, for a given amount of media, is a predictable and easily engineered nozzle design characteristic. The nozzle throat area always must be smaller than the smallest blast hose diameter. The diameter of the throat area dictates the air flow requirement in CFM needed to transport media. The ejector type (double venture) nozzle is used with soft abrasive and fan type nozzles are used to strip polyurethane topcoats from composite surfaces.

2.4 MEDIA RECOVERY SYSTEMS.

2.4.1 Introduction. Cleaning up after blasting, which includes removing dust from the blasted surface, and the loss of reusable media absorbs approximately 40% of the overall blasting costs. Therefore, recovery systems must have a way to deliver blasted media to a central recovery point, transporting the media from the central collection point to a cleaner system, and separating and filtering the dust, fines and other unwanted material from the media before it enters the blast machine for reuse.

2.4.2 The choice of a recovery system depends largely on the degree of automation desired to deliver the media to the central recovery point. The components of the system that transport the media from the central collection point to the separator and back to the blasting machine normally are automated. A hopper recovery system requires that media be manually transported to the central recovery point. With this type of operation approximately 25% of the production time should be allocated to shoveling the media into the hopper. However, the initial cost is low, making them a good choice when intermittent use is anticipated. In an automated recovery system, blasting media falls through a floor grate and gets carried to the bucket conveyer, auger, or other device by a mechanical floor transporting system or a vacuum that draws the media into a suction pipe designed as part of the floor grid system. The vacuum also can be manually operated as a permanently mounted system or it can have mobile units. With the automated system, operators blast continuously, losing no time for clean up, and the initial cost for a fully automated recovery system is frequently offset by the increased productivity.

2.5 HEAVY - DENSE PARTICLE SEPARATION

2.5.1 Introduction. The reclaiming process consists of aerodynamic separation through a cyclone centrifuge, a dual adjustable air wash, multiple vibrating classifier screen decks, and a magnetic separator. Paint debris and other foreign matter are removed and routed to a disposal container and cleaned media is ready for reuse. This system is highly efficient and acceptable for most operations; however, it will not remove nonmagnetic particles like sand. Heavy particle contamination is linked to increased crack growth rates and loss of fatigue life in metal test specimens simulating aircraft skins. Military specifications preclude the use of plastic media on aerospace products, if such contamination exceeds 0.02% of weight (200 parts per million) of the blasting media. In large open bay blasting operations, where aircraft routinely are stripped, heavy particle contamination must be addressed by the use of a separate heavy particle separator in addition to other reclaiming systems. Research into separation techniques has led to investigations into cyclone-type separators, gravity separators, aspirators, fluidized bed separators, electrostatic separators, and hydro-cyclone separators using FREON 113 (Tm).

2.5.2 Why Separate Heavy Particles?

2.5.2.1 The Materials Laboratory at Wright-Patterson AFB, OH, issued a report in Dec 85, titled "Evaluation of the Effects of a Plastic Bead Paint Removal Process on Properties of Aircraft Structural Materials." It appeared that the end of PMB as a paint removal process was at hand. Then in Jul 86, Battelle's, Columbus Division, issued an engineering report titled "Plastic Bead Blast Materials Characterization Study," which indicated that contaminated plastic media may be the reason for poor fatigue life test results. This was verified in Nov 87 by another Battelle engineering report titled "Plastic Bead Blasting Materials Characterization Study Follow-up Report." This report, which centers on unusual coating residue or plastic fines associated with the use of recoverable plastic, indicates that these contaminants are readily removed by the use of a cyclone separator, and a properly adjusted and maintained pneumatic recovery system. The contaminants causing the problem are "high density" or "heavy particle" material, which have a higher specific gravity than the plastic media. These contaminants are defined by T.O. 1-1-8 as sand, glass, and other silicate based materials; aluminum, magnesium, iron, and zinc based metals; paints and sealants; and, high density plastics.

2.5.2.2 Contaminants may be introduced into the blast room by improperly preparing work-pieces or be allowed by poor procedures that control entry. Before entering the blast room, aircraft tires, wheels, and flap wells must be inspected and pressure washed to remove sand and other high density contaminates. Sand or other high density grit may be removed from the clothes and shoes of operators as they enter the blast room by passing through a controlled entry room or airlock. This type of room or airlock also will remove dust and plastic media from the workers as they leave the blasting area.

2.5.3 Methods of Removing Contamination.

2.5.3.1 T.O. 1-1-8 says that at least 0.02%, or 200 parts per million, of contaminants must be removed from aircraft stripping applications. The T.O. identifies two chemicals for use in separating samples of plastic media to determine contamination levels. The first step involves adding trichloro-triflouro-ethane (TTE), which causes light contaminants to float, while heavier materials sink. Using a separatory funnel, the heavy contaminants are drained from the bottom, and it's weight is compared to that of plastic media. In the second step, bromo-chloro-methane (BCM) is used to sample the fraction of the total contamination that is "high density," such as the silicate based materials and metals. The settled contamination from the first step goes into another separatory funnel and BCM is added. Some of the contaminants that sank in the first separation will float in the BCM, while the ones with the highest density will remain at the bottom. The ratio of weight between these high density contaminants and the original media sample determines the media usefulness for aircraft applications. Because TTE and BCM are hazardous, however, they can be used only in small quantities at infrequent intervals for testing. In addition the chemicals would cost to much, if they were used in production.

2.5.3.2 A variety of dry methods can be used to separate plastic media from high density contaminants. They are similar to the wet process, since the specific gravity rather than the type of product or elemental makeup determines the final separation. All dry methods involve some type of air fluidizing, where air streams suspend the media, as if it is weightless, allowing heavier particles to drop. This method of separation differs from a cyclone separator, which blows particles into a vacuum cylinder, usually from a tangent entry point, in a spiral motion that forces all the particles to the outside of the cylinder by centrifugal force. A vacuum at the top of the cylinder creates a central vortex in which all particles spiral to the outside of the cylinder and drop to the bottom. The plastic media is reclaimed by allowing air to enter the bottom of the cylinder through adjustable air gates and entraining dust and plastic fines which are conveyed to the vortex. By allowing more air to enter, larger plastic particles are entrained and carried through the vortex to the vacuum source and dust collector.

2.5.3.3 Cyclone separators, which are not very sensitive, do not differentiate between particle size or specific gravity, yet they effectively and economically separate fine dust and plastic. The wide range of plastic media types, sizes, and contamination ratios and the requirement to constantly adjust the system, makes the cyclone less desirable than other dry separators.

2.5.4 Heavy Particle Separators.

2.5.4.1 PMB systems have rapid and highly efficient media recovery/reclaiming components consisting of aerodynamic separation through a cyclone centrifuge, a dual adjustable air wash, a vibrating screen deck with multiple classifier screens, and a magnetic separator. The purpose of these systems is to recover/reclaim media for reuse, not to separate hazardous waste. No separation techniques have been developed that will remove chromium, cadmium, lead, and other leachable toxins below current Environmental Protection Agency (EPA) limits. Most of the paint chips, blast room debris, and other foreign matter are separated from the media. However, not all heavy particles are separated and the systems must be augmented with secondary heavy particle separators to sift and segregate these remaining contaminants. There are three basic systems/techniques on the market to perform this function.

2.5.4.1.1 Fluidized Bed System. This type system floats media on a liquid or air bed where the good media floats on the surface and the heavy particles sink into the flotation medium. Liquid systems using water mixed with soluble agents to increase the specific gravity have been studied, but none is in use. Development of liquid separation was discontinued for industrial use because the liquid material adds the complexity of having to remove the liquid before the media is reused. Ogden Air Logistics Center (OO-ALC), Hill AFB, has used two different fluidized bed systems. Both demonstrated an inability to quickly separate the heavy particles without a large lose of good media. The problem, in particle size distribution, was identified to the processor from 12 to 60 mesh plastic particles and the change from type II to type V media. Also, the large volume of media being processed seemed to overload the system's cleansing ability. OO-ALC's system has been removed for upgrades in the design.

2.5.4.1.2 Air Wash System. The air wash system is economical and relatively simple. Normally, these systems are off line, but they can be configured for on-line, continuous use. A version of the air wash system called the "clean machine" is used at Randolph AFB, TX. Several versions of the clean machine incorporate six basic steps.

1. A vibrating screen device to remove gross contamination, such as oversized media, dirt, pebbles, masking tape, nuts, bolts, washers, and bugs.

2. An air wash system, typically a high efficiency cyclone separator, to remove plastic fines and dust.

3. A permanent magnet to remove ferrous metal particles.

4. A multiple-stage vibrating screen system to sort and classify contaminated media.

5. An air separator for heavy particles.

6. An air conveyor system to return the cleaned media to a receptacle for reuse.

2.5.4.1.3 Inclined Vibrating Deck System. The system works by passing media through three tiers of screens, before sending it to the heavy particle separator. It's most important use is to separate media of the same mesh by specific gravity, although it will effectively separate media by mesh. The system treats particles of the same mesh and differing specific gravity as contaminants. It also separates particles with differing specific gravity and different mesh, but not very efficiently. Operators must adjust the following variables for proper separation.

1. Feed Rate. The feed rate controls the amount of media allowed on the separating deck. It should flow out of the hopper homogeneously, avoiding surges. The feed rate determines the capacity and efficiency of the heavy particle separator.

2. Tilt. The tilt is the angle of the separating deck. Increasing the tilt causes the media to flow toward the low end (reusable media) of the deck. Decreasing the tilt causes the media to flow toward the high end (contaminant side) of the deck.

3. Eccentric Speed. Eccentric speed is the rate of oscillation of the separating deck. Increasing the eccentric speed causes the media to shift towards the high side of the deck; while decreasing the eccentric speed causes the media to shift towards the low side of the deck.

4. Air. Air is the stratifying agent. Too much air will cause a bubbling or boiling effect. A proper air setting causes the bed of media to be almost fluid in appearance.

2.6 PM WASTE TREATMENT AND DISPOSAL

2.6.1 Introduction.

2.6.1.1 Environmental restrictions on both hazardous waste disposal and air pollutants are the major thrust behind the investigation of alternative paint stripping methods. The authority for regulating hazardous waste is given to the federal government by sections under the Resource Conservation and Recovery Act (RCRA) of 1976. The important regulations for managing paint stripping waste streams are found in Protection of Environment, Title 40, Part 261.3 of the Code of Federal Regulation (CFR). Other regulations are CFR 49, Transportation, Part 172 and CFR 29, Occupational Safety and Health Administration (OSHA) Standards, Subparts H and Z. These regulations identify and control the generation, storage, transportation, and disposal of hazardous waste. The Environmental Protection Agency's (EPA) 1988 regulation allows 3.3 lbs/day for total toxic organic (TTO) discharge. In 1990 the EPA regulation expanded restrictions on leachable hazards from eight heavy metals to include an additional 25 chemicals in the fuel, solvent, pesticide, insecticide, and devegetation areas. As this new regulation, referred to as the Land Ban, becomes effective, no leachable materials may be land filled. EPA and OSHA regulators will continue to decrease the allowable levels of hazardous materials in the work environment, generation of toxic solid waste, and the release of air pollutants.

2.6.1.2 Most of the maintenance organizations investigating PMB use chemicals, such as methylene chloride, phenols, and strong acids and mechanical sanding methods to remove coatings. The chemicals typically used as stripping components are labeled toxic by the EPA. Because they are potentially colicinogenic, carcinogenic, or mutagenic. Personnel working with these chemicals are required to wear protective clothing to guard against inhaling, ingesting, and absorbing the chemicals into their skin. Besides the potential for inhaling volatile organic compounds (VOC), there is the release of toxic air pollutants into the atmosphere. In addition the organic stripper must be rinsed from the work piece and work area. Up to 10 gallons of water is required to strip each square foot of substrate and the entire liquid volume is considered contaminated. Phenols, which tend to kill the active bacteria/organisms used to cleanse water, often are used as activators. They must be removed by an intermediate bio-separator before the water can be sent to the industrial waste water treatment plant. Alternative paint stripping chemicals are being developed, but, other alternatives are being tested and used.

2.6.1.3 PMB, as an alternative to chemical stripping, generates a great deal less hazardous waste. The major problem is plastic dust and paint chips intermingled with the dust. Additionally, there is very little rinsing of the stripped substrate and there are no toxic substances handled. Disposal options include solidifying the plastic dust and dumping it in appropriate land fills, burning it in approved hazardous material incinerators, or using it as a fuel additive in authorized cement kilns. Another alternative is to pay the media supplier to take the waste media back for recycling. Also, bio-remediation, which has been studied under an Air Force Materials Laboratory program, has resulted in biologic agents, bacteria, and fungi that will readily attack paint chips within plastic media and will bio-degrade type V, acrylic plastic waste. The current trends is to avoid incineration and use approved land fills for disposal; however, as the cost of using land fills ,rises incineration or cement kiln incineration becomes more attractive.

2.6.2 Treatment.

2.6.2.1 PM waste is hazardous only because it often has the characteristics of extraction procedure (EP) toxicity, which is a procedure mandated by the EPA under RCRA law as one of the tests to be performed to determine whether a waste is hazardous. In the EP toxicity test, 100 grams of a solid are extracted with 1600 ml of water adjusted to pH 5 +/- .2 with acetic acid. After the final volume is adjusted to two liters, the concentrations (usually in units of milligrams per liter) of eight elements are determined. If the concentration of any element of concern in the waste extract exceeds the maximum established by the EPA, the waste is regulated as hazardous. The toxic levels outlined in the EP toxicity level test have remained the same, but new chemicals have been added to the list. The new test is called the toxicity characteristics leaching procedure (TCLP). The following are EP toxicity limits for the metals of concern.

Arsenic	(AS)	5.0 mg/L (ppm)
Barium	(Ba)	100.0 mg/L (ppm)
Cadmium	(Cd)	1.0 mg/L (ppm)
Chromium	(Cr)	5.0 mg/L (ppm)
Lead	(Pb)	5.0 mg/L (ppm)
Mercury	(Hg)	1.2 mg/L (ppm)
Selenium	(Se)	1.0 mg/L (ppm)
Silver	(Ag)	5.0 mg/L (ppm)

The following is an example of the EP toxicity values for various PM waste samples.

Sample#	Chromium	Cadmium
1	12.2	0.19
2	39.0	1.6
3	25.0	0.17
4	12.5	0.2
5	21.0	1.1
EP Limit	5.0	1.0

The following is an example of EP toxicity test results for a sieve separated sample.

Media Size	% of Total	mg/L Cadmium	mg/L Chromium	mg/L Lead
unscreened	100.0%	1.70	28.1	<0.2
>50 mesh	17.7%	0.23	1.5	<0.2
50 - 100	32.1%	0.40	13.0	<0.2
100 - 200	23.4%	1.07	52.0	<0.2
200 -400	13.9%	3.71	80.0	<0.2
<400 mesh	12.3%	6.9	68.0	<0.2

2.6.2.2 Aerodynamic Classification of Waste Media. Aerodynamic separation is one way of classifying PM waste into hazardous and non-hazardous volumes. Plastic waste particles and paint chips, which are chromium free or chromium bearing, have very similar sizes and densities but are shaped significantly different. Thus, using aerodynamic separation principles to separate to separate particles based on density and drag coefficient should result in designs capable of sifting the hazardous material from the blast media during service or those capable of segregating hazardous material from waste dust in a post blast cleanup system. Aerodynamic classification usually is faster, more adjustable, more efficient, and less expensive than mechanical sieve screening systems. However, tests conducted by Hill AFB were successful. Additionally, separating the particles into different sizes did not allow larger or smaller particles to individually pass the toxicity test.

2.6.2.3 PM Waste Encapsulation in Cement. Hazardous waste contractors solidify PM waste for land filling with cement. As the amount of waste in the cement increases, the strength of the encapsulating product decreases. Encapsulated products pass EP toxicity tests although the long-term leachability effects of cement encapsulated hazardous waste has not been determined. Test results indicate that aggregates containing 50% of PM waste should pass the tests, yet no compositions containing this much waste residue have been tested.

2.6.2.4 Chemical Leaching of Hazardous PM Waste. Waste samples having EP toxicity values of about 10 mg/L chromium, 0.32 mg/L cadmium, and less than 0.05 mg/L lead have been chemically treated. The test sample was extracted using 200 ml of 10% concentrated hydrochloric acid solution per 100 grams of waste material. The extracted solids were washed and a standard EP toxicity test was performed. The 10% hydrochloric acid leach did not render the waste nonhazardous. The chromium removal was successful since an EP toxicity test on the extracted material showed a chromium concentration within the 5 mg/L limit. However, only a small amount of the cadmium was removed from the concentration, which still exceeded the 1 mg/L limit. Worse yet, the hydrochloric acid leach removed a small amount of available lead, but solubilized the remainder so that the material failed the EP toxicity tests with the concentration exceeding the limit of 5 mg/L. Thus, lead and cadmium EP toxicity values are worsened by using hydrochloric acid extraction.

2.6.2.5 Charring PM Waste. Heating small quantities of PM waste to 1382 degrees Fahrenheit (750 celsius) and holding the temperature there for 15 minutes gives a light-colored ash that is free of carbon or combustible organics. The waste is reduced to about 75% on a dry basis. The char easily passes the EP toxicity tests performed on the ash with a chromium level of .3 mg/L, cadmium level of .2 mg/L, and a lead level of .1 mg/L. Insoluble forms of chromium or oxides of chromium are apparently created and some of the cadmium may be released into the atmosphere during the charring process. Thus charring, which is acceptable for having PM waste classified as nonhazardous, can create air emission problems.

2.6.2.6 Flotation Separation of PM from Paint Waste. The concept of using a liquid to float nonhazardous plastic dust, but to sink heavier paint chips has been studied using different chemicals to separate the various media particles from commercial and military paint chips. A sample of PM waste with a bulk specific gravity of 1.42 was stirred into a solution of ferric chloride having a density of 1.42 gms/L. After 8 hours the waste had separated into two factions, one of which sank to the bottom and the other floated on the surface. Results of EP toxicity tests on the two layers show a reduction in chromium from 18 to 0.5 gm/L, cadmium from 1.08 to 0.38 gm/L and no change in lead content to .2 mg/L. The float concept exhibited a significant decrease in total metals and passed the test. This method has been lab tested but has not been developed into a production system.

2.6.2.7 Bio-degradation of PM/Paint Chip Waste. Research into the use of fungal and bacterial systems for PM waste treatment has resulted in two demonstrated systems with the capability. Fungal bio-systems that attack and solubilize acrylic media to reduce the volume of plastic waste requiring disposal. Bacterial bio-systems attack the paint chips and solubilize them. Paint chips contain the hazardous materials, so removing them, makes the remaining media nonhazardous. The concept has been demonstrated in the laboratory using small volumes of actual waste media from Kelly and Hill AFBs and bio-systems engineering for a continuous PM bio-reactor is in progress.

2.6.3 Disposal.

2.6.3.1 The EPA land ban program that now prohibits some 35 or more hazardous leachable chemicals from being land filled has effectively changed the outlook of waste disposal. Plastic media waste must pass the EP toxicity test to be placed in any land fill. The class A hazardous land fill permit apparently is eliminated. This means all waste material must conform to limits and undergo leaching test specifications before being dumped at any land fill. To PMB operations, this means the material must be charred, detoxified by leaching out the hazardous chemicals, introduced to a biological agent, or encapsulated enough to pass the leaching test. Presently the cheapest means of preparing the material for the land fill is encapsulation. However, the EPA favors incineration by cement kilns for fuel supplemental waste products, like plastic waste, fuels, oils, flammable non-chlorinated solvents, and so forth. Hazardous waste incineration methods must be used for wastes that cannot be recycled, reprocessed, or otherwise reclaimed.

2.6.3.2 Incineration. Burning PM waste by-products is the most expensive disposal method available. One drum filled with 53 gallons of hazardous waste, for example, costs from $400 to $1200 to incinerate through hazardous waste contracts. The PM is transported to an approved incinerator and placed into the furnace at 2200F degrees, which completely incinerates the plastic and transforms the heavy metals into vapors, oxides, and ash. The resulting ash waste is tested for leachability, then disposed of in a land fill.

2.6.3.3 Cement Kiln Disposal.

2.6.3.3.1 Cement kiln incineration is a documented, proven process for disposing of a variety of energy bearing solid and hazardous waste materials. EPA guidelines for complete incineration require subjecting most toxic materials to 2200F degrees for at least two seconds. Plastic media is an energy bearing material used to supplement coal as the energy source for the cement kiln, which operates at 3000F degrees in the burning zone. At this elevated temperature the waste undergoes chemical and physical reactions as it is burnt, leaving heat, water, carbon dioxide, and by-products. Organic materials are destroyed while inorganic materials are rendered inert as they are chemically bound to and incorporated within the lattice work of the cement clinker. The clinker is a product of the kiln that is formed by melting and combining materials at high temperatures.

2.6.3.3.2 Environmental Concerns. The concerns of hazardous waste generators that use cement kilns to destroy and recover resources include kiln stack emissions, air pollution, product quality, and liability. The EPA's boiler and industrial furnace regulation from EPA says that the stack must meet emission standards and that the cement kiln dust is not significantly impacted by the burning of waste. The cement, which is a safe commercial product, effectively meets all land treatment standards. Stringent testing has shown that the product will not leach under EP toxicity test procedures. Each cement kiln must have all necessary state, regional, and federal permits and show regulatory compliance to obtain authorization for hazardous waste disposal.

2.6.3.3.3 Cement Kiln Process. The amount of plastic media used in cement kilns is minute compared to the volume of coal required. A single cement kiln could consume the entire civilian and military waste stream estimated at over two million pounds per year. Plastic media cannot be simply added to the coal because of conditioning and the coal injection system. Also, coal injection occurs at temperatures up to 600 degrees fahrenheit, which would alter or char the PM during the process. Solid waste supplemental fuels must contain 8,000 BTUs of heat per pound. Acrylic and polyethylene plastic yields 11,000 to 17,000 BTUs per pound while urea and melamine formaldehyde, which only supply 7,000 BTUs per pound, are less desirable. Combustion temperatures at the area of supplemental fuel injection are maintained at 2,000 degrees F and the kiln temperature at the flame is 2,800 degrees F. Thus, the kiln destroys the plastic and inerts the chromium, cadmium, and lead trace metal contaminants, leaving no residue tog dispose of. The costs for system modifications and for environmental permits are passed to the waste generator. Using a cement kiln to destroy PM waste costs between 50 and 90 cents per pound. The Defense Logistics Agency has initiated an effort to list large hazardous waste streams as single items for disposal contract bids. This will permit greater use of the cement kiln process by organizational and depot maintenance facilities.

2.6.3.4 Recycling PM. Thermoplastic media, such as type V acrylic, can be recycled by heating the media to a liquid or plastic state and reforming it. This involves mixing and encapsulating waste into a hardened form that exhibits the non-leachable, non-toxic characteristics required for reuse in the public sector, or using the waste material as a bulk filler in construction materials. Also, type V media can be used as a raw material source for manufacturing new acrylic sheet. In this process contaminated plastic blast residue is shipped in bulk to a processing plant where the material is heated to recapture the plastic monomer. Implementing a recycling program is difficult because contractors supplying the recycling service require that the media be purchased from them (sole source procurement). The Coast Guard maintenance facility at Elizabeth City, NC, has incorporated a type V media recycling program. However, Air Force maintenance organizations that have evaluated type V media recycling options have not incorporated an active program. Primarily because the cost would add 60 cents/lb to the media purchase price. In addition, the only material authorized for use in the recycling programs is grade A, which cost approximately $2.50/lb. The maintenance organizations often purchase grade B media at $1.60/lb.

2.7. BLASTING CABINETS

2.7.1 Introduction. Blast cabinets can use suction or direct pressure systems. The suction systems are less expensive because they sacrifice precise blasting process control for simplicity. Ideally, they are suited for general cleaning and occasional use. On the other hand, direct positive pressure blast cabinets are used more often with plastic media because they are versatile, controllable, more consistent, and better suited for applications such as aircraft components.

2.7.2 Direct Pressure Cabinet. The pressure cabinet is a self contained, dust free, dry stripping system designed for cleaning aircraft components and similar work pieces. The cabinet systems typically are used with type II media for removing coatings from aircraft wheels, brake housings, landing gear assemblies, and so forth. Surface cleaning is accomplished by a stream of media suspended in and propelled by a high velocity air stream that is directed through a 1/4 to 3/8 inch diameter conical blast nozzle at a work piece inside the blast cabinet. After striking the work surface, media and debris are pneumatically conveyed to the reclaiming section for cleaning. Inside the reclaiming section,the controlled cyclonic action spirals the media and debris, throwing good (heavier) media particles to the outer walls where they spiral down through a two-stage air wash system that enhances the separation of dust and other fines from the reusable media. A vibrating screen below the cyclone traps oversized debris, allowing correctly sized, reusable media to pass through to the storage hopper mounted over the pressure vessel. Dust and other fines are pulled from the center of the cyclone and pneumatically conveyed to the dust collector. Each time blasting stops, the pressure vessel automatically exhausts and refills with clean reclaimed media.

2.7.3 Pressure Cabinet Limitations. Limitations to the blast cabinet include size restrictions to the work piece and limited use of blast parameters, such as impingement angle and standoff distance. Only open blasting in a booth or blast facility gives the flexibility needed to blast many delicate or highly contoured surfaces that require good visibility and delicate process techniques to remove the coating without damaging the substrate. The size of the cabinet can vary to include multiple blast hoses and operators, however, the limited visibility and fixed position of the rubber gauntlets dictate the reach and viewing capabilities. Cabinets primarily are used for parts to replace or augment chemical stripping operations. Some parts are first treated in chemical stripping baths, then used in a cabinet to quickly remove the residual paint not stripped chemically.

2.8 BLASTING BOOTHS

2.8.1 Introduction. A blasting booth can be any structure that contains or accumulates the plastic media during blasting. They may be simple backstops that collect media thrown in one general direction or temporary enclosures made of removable plastic sheet. Because production conditions vary from plant to plant, every blast booth is customized to some extent. The application of the blasting booth drives the selection of the blasting abrasive and the type of component determines the capabilities of the room, the degree of labor involvement, the cost, and the return on investment. The booth's enclosure, ventilation, and dust collection system, the media cleaning and recovery system, and the work handling system are planning decisions that can only be made after the process method is chosen. The work handling system has a significant effect on the component selection for the structure flooring and recovery system. The floor grating support structure and recovery system design are influenced by the required weight-bearing capacity. This capacity is dictated by the means of carrying the work into the booth: monorail, work cart, or fork lift. Also, the blast booth simply may rest on a concrete floor coated with a hard material that will resist erosion and employ a vacuum to recover media from manually filled collection points.

2.8.2 Enclosure. The size of the enclosure is dictated by two factors, the dimensions of the largest part to be blasted and the number of operators in the room at one time. For the best production and safety, a minimum clearance of four feet on all sides of the part is recommended, with additional height, as required, for the work handling system. The planner for the enclosure must balance the convenience of extra space with the higher initial costs added by the increased requirements on the dust collector and ventilation system. The logical location for the blast booth is between the final fabrication or work area and the painting or finishing area. Painting and blasting is not recommended in the same area. A staging area in front of the enclosure may be desirable and the planner should consider putting doors at both ends for handling flow-through work. Man doors, which can be installed in any wall panel, are required by OSHA for rooms over 30 feet long.

2.8.3 Dust Collector. Size is the only variable with dust collectors. For standard, end-draft rooms, the collector size is determined by the cross-sectional area of the enclosure, the type of abrasive used, and state and local regulations on air pollution control. Dry fabric dust collectors are conventionally used. In most cases the "air-to-cloth" ratio is 4 to 1. This is the ratio of ventilation throughput in cubic feet a minute (CFM) to filtering cloth in square feet. Most states require a ventilation rate in end draft rooms of 50 feet/min for steel grit, 80 ft/min for silica sand and normally 60 to 75 ft/min for plastic media, but can go as high as 80 to 100 ft/min. One total change of air per minute is also required, irrespective of rate.

2.8.4 Ventilation. Ventilation is provided by the dust collector exhaust fan. The end-draft system is the most common, efficient, and low cost. These have baffled and screened inlets located in the doors that permit a minimum air influx of 500 feet a minute which is high enough to prevent dust from escaping through the inlets. The outlets are normally located in the end wall opposite the doors. In rooms with doors at both ends, the outlets are normally placed in the side walls as close to the downstream end as possible. Down-draft systems are usually designed to meet special needs or may be required by law in some states. Also, portable ventilation systems may be used when normal air flow patters are disturbed by placing large articles in the blasting room.

2.8.5 Portable PMB Facilities.

2.8.5.1 There is a growing demand for portable PMB systems. The increased need may be attributed to several factors related to the availability of a capability to service multiple sites, to transport to remote sites, or to replace existing stripping operations upon short notice. The portable/mobile PMB system should be field capable, be cheaper than fixed-base systems, be transportable, and be capable of being incorporated into existing buildings/structures for temporary use.

2.8.5.2 Turnkey Systems. Self-contained tractor/trailer systems, with the trailer serving as the blast room, are available for stripping components and small structures. However, where the capability to strip larger structures is required, such as small airframes, communication shelters, aerospace ground equipment, etc., a portable turnkey PMB system is desired. The following is a description of possible configurations.

2.8.5.2.1 Blast Room. A blast room can take several forms such as an inflatable structure, specially designed tent, ruggedized canvas panels, or a standard 18 gauge galvanized blast booth. These booths, supplied with cad/cam exploded drawings and pre-numbered panels, can be easily transported on a flat bed trailer and can be erected in a relatively short period of time. Preferably, they should be installed on a concrete pad or the floor of a weather-proof building or structure.

2.8.5.2.2 High Density Particle Separator (HDPS) System. Where a military or commercial customer is involved in stripping airframes and aerospace components, they may have to comply with specifications related to the maximum permitted contamination of plastic media from high density particles such as sand and non-ferrous material. The PMB equipment manufacturers have each developed a HDPS system which meets and exceeds the existing procurement specifications of the military Services and commercial airframe manufacturers. These systems, with their compact design lend themselves readily for use with a portable PMB system.

2.8.5.2.3 Ventilation. All blast booths should incorporate a ventilation system which provides the requisite linear air flows for excellent visibility and to create negative air pressure in the booth or within containment panels or curtains, especially at remote sites. A ventilation system is easily installed in the rear panels of a metal blast booth or a portable, self-contained system may be used. Such units are usually positioned on a specially designed highway trailer, complete with an electric generator and a large diesel fuel reservoir.

2.8.5.2.4 Lighting. Excellent lighting should be incorporated in the portable/mobile system, especially for the stripping of sensitive substrates, such as thin metal, fiberglass, and advanced composites. Standard lighting should be 100 foot-candles at 3 foot above floor level.

2.8.5.2.5 Facility Interface. All components of portable/mobile turnkey PMB systems should be capable of interfacing with both stationary and portable compressed air and electrical energy sources. The compressed air source for a one-nozzle PMB system is normally a 50 HP rotary screw air compressor with refrigerated air dryer, capable of producing 185 to 200 + SCFM at 100 PSIG. It may be either a stationary electric, gasoline, or diesel compressor. All electrical voltage should be 3 phase, 60 HZ, supplied from either a fixed source or by a portable electric generator.

2.9 LARGE PMB FACILITY DESIGN

2.9.1 Introduction. The largest PMB facility in the Services inventory is located at the San Antonio Air Logistics Center, Kelly AFB, TX. The hangar envelope is sized to house any aircraft in the Air Force's inventory. The primary concern in the design development was to be able to process the C-5 and B-52 aircraft, then secondary consideration was given to housing multiple smaller aircraft. The facility design allows ceiling clearance of approximately 20 ft over the C-5 aircraft. This was necessary to provide room for overhead telecranes to maneuver around the aircraft. The area of the main hangar is 58,146 sq ft.

2.9.2 Ventilation.

2.9.2.1 Industry and government standards require ventilation rates of 60-100 feet per minute for similar processes but no established criterion existed for ventilation rates for a PMB operation of this size. At these rates the facility envelope could not be cost effectively ventilated using any sort of conventional ventilation techniques. Existing standards concerning ventilation requirements are summarized as follows.

OSHA 29CFR 1010.94(3)(B) - The rate of exhaust shall be sufficient to provide prompt clearance of the dust-laden air within the enclosure after the cessation of blasting.

Air Force Occupational Safety and Health (AFOSH) Standard 161-2 - Provide minimum down draft ventilation over the entire floor area of 60 fpm for class II enclosures (class II enclosures are those in which materials not containing free silica are used) and for enclosures with room length-to-width ratios of 2 to 1 or less. For room length-to-widthratios in excess of 2 to 1, provide ventilation not less than 75 fpm through cross-sectional area for class II enclosures.

Naval Civil Engineering Laboratory (NCEL) CR 87.006 - Recommends 50 ft/min minimum air flow rate be maintained in a PMB blast facility. This would avoid any possibility of reaching an air/contaminate mixture which would be explosive.

American National Standards Institute (ANSI) Z 9.4 - This standard is primarily targeted for blast rooms to 400 sq ft, and it recommends 60 ft per min ventilation rate be used for cross draft ventilation systems and 20 ft per min be used for down draft systems. It also states the primary reason for the ventilation system is to keep combustible dust particles to no more than one-fourth the minimum dust explosive concentration for that particular abrasive.

The reasons for designing a proper ventilation system in a large PMB facility are: to keep the concentration of contaminants in the breathing zone of the abrasive-blasting operator or any other employee below applicable occupational exposure limits; to keep airborne concentrations of combustible dust particles to 25 percent of minimum dust explosive concentrations; and, to keep dust levels down such that the visibility of the operator is not impaired.

2.9.2.2 Personnel Exposure.

2.9.2.2.1 The first consideration in design of the ventilation system deals with exposure of the operator or any other person who may be exposed to the airborne contaminants. OSHA 29 CFR 1910.94 states that a continuous flow airline respirator shall be worn by all abrasive blasting operators; therefore, the operator is adequately protected during the blasting operation whether you have an adequate ventilation system or not. Upon termination of the blasting process, the time required before the respirator can be removed by the operator is dictated by the performance of the ventilation system. As defined by OSHA, 15 milligrams total dust per cubic meter of air is the maximum allowable level for nuisance particles for personnel exposure. The time required to clear the air before the operator can remove his respirator is important in the ventilation design. If the ventilation system is inadequate, the operators could be required to wear the respirator anytime they are in the hangar or blasting envelope. This could cause some serious operational problems. It is wise to design the system such that an operator can remove his respirator soon after the cessation of the blasting operation and move freely about the hangar performing other tasks.

2.9.2.2.2 An analysis of particle size distribution was done by Battelle Laboratories on various types of media. Type I exhibited a consumption rate of 7.97% (for the purpose of bio-environmental considerations, consumption means particles smaller than 150 microns). Type II exhibited a consumption rate of 9.96% and type V exhibited 2.4% rates. The type V media is used in the facility and are the basis for the calculations. With 20 nozzles blasting at a 2.4% consumption rate, there is 230 lbs/hr (20 Nozzles X 480 lb/hr X 2.4% = 230 lbs/hr) of total dust smaller than 150 microns available for suspension in the hangar. The maximum allowable level for total dust as required by OSHA is 15 milligrams per cubic meter or 0.000935 lb/cubic ft. Since 2.4% of the media is less than 100 mesh and considered a nuisance, it requires (X) hrs to achieve a homogeneous concentration above OSHA requirements.

$$.000935 \text{ lb/cubic ft} = 230 \text{ lb/hr X (X) hrs per } 3{,}347{,}500 \text{ cubic ft}$$
$$\text{then X} = 14 \text{ hours}$$

It requires 20 nozzles blasting for 14 continuous hours, assuming 100 percent mixing, before a nuisance dust level could be reached. With settling velocities of 7 ft/sec, for a 60 mesh particle, and 3.8 ft/sec, for a 200 mesh particle, the dust will settle out of the hangar long before a nuisance level is achieved. When the ventilation system is on some small particles may have a tendency to remain suspended from turbulent air flow. The ventilation system is designed to minimize this turbulent air flow and to provide a minimum velocity of 100 ft per minute across the surface of the C-5 aircraft. At this rate the operator only has to wait a few seconds for the air to clear before removing his respirator. Other people in the hangar, more than 50 ft from the blasting operation, will not be required to wear a respirator. Remember these are design conclusions and are continually tested and verified for the establishment of operational procedures. Even though the nuisance dust levels are low, the toxicity of the dust must be measured and compared to the exposure limits as defined by the appropriate regulations. This toxicity is largely dependent on the coatings being removed.

2.9.2.3 Combustible Dust. The second consideration in designing the ventilation system was to prevent the possibility of a combustible concentration of dust from existing in the blasting facility. The Bureau of Mines performed an investigation into the explosibility and ignitability of plastic abrasive media for the Navy in Jun 87. This report showed that the type V media would not ignite when particle sizes were larger than 40 mesh or 425 microns and the minimum explosive concentration is 110 g/cubic meter. The Battelle analysis of the breakdown rate of the type V media demonstrated an average 6.35% consumption, when consumption is considered to be all particles 60 mesh or smaller, unlike the consumption rate discussed in the previous paragraph for nuisance dust. Actual production experience at the SA-ALC has shown that particles smaller than 60 mesh are no longer economically viable for a production aircraft stripping operation. These smaller particles, however, can still remove paint at a slower rate, but not economically. The classifying system in this hangar will reject all particles 60 mesh or smaller. When 20 nozzles are blasting at a 6.35% consumption rate there will be 658 lb/hr (20 nozzles X 480 lb/hr X 6.35% = 658 lb/hr) to total dust smaller than 60 mesh available for suspension in the hangar. For an explosive concentration to exist 110 g/cubic meter must be suspended in the hanger. The time required before an explosive mixture can be obtained is:

$$.00686 \text{ lb/cubic ft} = 658 \text{ lb/hr} \times (X) \text{ hrs}/3{,}457{,}500 \text{ cubic ft}$$
$$\text{then } X = 36 \text{ hrs}$$

Therefore, 36 continuous hours of blasting with 20 nozzles is required to reach an explosive concentration. ANSI Standard Z 9.4 requires that you maintain dust levels to no more than 1/4 the minimum dust explosive concentration or .001715 lb/cubic ft. To do this you would have to blast with 20 nozzles for 9 hours, assuming 100% mixing, to maintain 25% of the lower explosive limit (LEL). After 9 hours of continuous blasting with 20 nozzles enough waste will have been generated to cause the entire volume of the hangar to reach 25% of the explosive range. This would require total mixing which will not happen. Since settling velocities for the dust will range from 3.8 - 7.0 ft/sec, only a few minutes are required to settle the dust. Gravity separation is acceptable for particles larger than 140 mesh, but not adequate for particles smaller than 140 mesh. Normal air fluctuations from people moving, doors opening and closing, outside air variations, etc. keep the dust in motion. Therefore, it is necessary to design the ventilation system so the escape of this extremely fine dust is minimized. San Antonio ALC uses a zoned down draft ventilation system that entrains most of the dust (less than 140 mesh) and exhausts it from the blast area. The ALC placed the supply air plenum directly over the exhaust plenum in the floor to create the down draft system. The high-velocity air supply was directed through diffusers directed at the aircraft surface with low-velocity air near the diffusers to replace the room air being entrained. All the air passing over the aircraft (including the entrained air) is then exhausted. Most of the dust should be captured by the low velocity air stream.

2.9.3 Fire Protection System. Air Force Manual 88-15 and NFPA 409 require a pre-action aqueous film forming foam (AFFF) closed head sprinkler system as well as a supplemental protection system to hangar a C-5 aircraft. The fire suppression system essentially is two independent systems that serve separate purposes: an overhead foam-water deluge system with closed heads protect the facility and a supplementary foam-water oscillating nozzle system to protect the aircraft. So the overhead system will not be accidentally discharged, it is activated by two separate sensors. A thermosensor returns an electronic signal and the other detection system senses a pressure loss in the sprinkler pipes when a fusible link head is opened. These two signals must verify each other before the overhead system will discharge. an ultraviolet-infrared detector discharges the supplementary oscillating nozzles. The two systems, which operate independently, will operate in conjunction if a single fire triggers both systems. The AFFF fire protection system provides maximum protection for the personnel, the aircraft, and the facility.

2.9.4 Electrical. The main hangar bay is designed around a Class II, Division 1, Group G electrical hazard classification, as described in the National Electric Code, for all areas 18 inches above the hangar floor. The area between the hangar floor and 18 inches, including adjacent rooms, is classified as Class I, Division 2, Group D. Areas below the hangar floor receive a Class II, Division 1 Group G classification. The lighting system, which provides at least 75 feet candle illumination throughout the hangar, consists of 50 percent metal halide and 50 percent high pressure sodium to provide a balanced color in the facility instead of giving the facility a yellow or blue hue.

2.9.5 PMB System. The blasting system consists of 20 half-inch nozzles supported by 20 blast pots. Each blast pot is six cubic feet. The system has two main storage hoppers, each capable of storing 115,000 pounds of classified media.

2.9.6 PM Classification System. The classification system can continuously process 20,000 pounds of media per hour. The system consist of cyclone air washes, vibratory screen decks, dense particle separators, magnetic separators, deionizers and two 144,000-pound storage hoppers.

2.9.7 PM Recovery System. The recovery system has been the most difficult to design. To provide an affordable ventilation system, the floor trenches had to serve multiple functions: the exhaust air plenum, the fire protection effluent reservoir, and media recovery system. A pneumatic recovery mechanism is located where the ventilation air passes through a louvered hopper. As the media falls to the bottom of the hopper, the recovery system returns it pneumatically to the classifier system.

2.9.8 Overhead Crane System. Five overhead cranes were installed in the facility to eliminate the use of static scaffolding. Historically, a complete set of static scaffolds mounted on casters are used for each aircraft processed. The time required to place and remove scaffolding for each aircraft was used to economically justify the overhead cranes. Four of the cranes have four axes of movement and the fifth platform moves about two axes. The cranes allow the operator to have hands-on access to virtually any aircraft processed in this facility. Four cranes can operate in the low bay (50 ft) portion of the hangar to access the aircraft fuselage and wings. The fifth crane operates in the high bay (80 ft) portion of the facility to access the vertical and horizontal empennages of the C-5 and B-52 aircraft. The fifth platform is double masted with a 70-foot long catwalk suspended between two mast. The four platforms in the low bay have single masts with a 20-foot cantilevered work platform attached to each. These platforms will rotate 360 degrees, non-repeatable, about the mast. Each crane has a rated live load capacity of 4000 pounds.

2.9.9 Design Standards and References.

AFOSH Standard 61-2 `- Occupational Health Industrial Ventilation.
AFR 88-15 - Criteria & Standards for Air Force Construction.
AFM 86-2 - Standard Facility Requirements.
T.O. 42B-1-22 - Quality Control of Compressed and Liquid Breathing Air.
AFOSH STD 161-1 - Respiratory Protection Program.
OSHA 29 CFR 1910.94(a) - Ventilation ~ Abrasive Blasting.
OSHA 29 CFR 1910.134 - Respiratory Protection.
OSHA 29 CFR 1910.35 - Means of Egress.
OSHA 29 CFR 1910.67 - Vehicle-Mounted Elevating and Rotating Work Platforms.
ANSI A92.2 - Vehicle-Mounted Elevating and Rotating Work Platforms
NFPA 70 - National Electric Code.
NFPA 68 - Guide for Venting of Deflagrations.
NFPA 69 - Explosion Prevention System.
NFPA 101 - Life Safety Code.
NCEL CR 91.001 - Operational Testing of PMB Equipment.
NCEL CR 87.001 - PMB Monitoring at Hill AFB, UT & NADEP, Pensacola, FL.
NCEL CR 87-01 - How to Reduce Explosion Hazards from PMB.
NCEL CR 87.006 - PMB Data Gathering Study.
NCEL CR 87.011 - Explosibility & Ignitability of Plastic Abrasive Media.
AFOSH 161-35 - System Safety Analysis for Corrosion Control Facility, Kelly AFB, TX.
NFPA 654 - Prevention of Fire & Dust Explosions in the Chemical, Dye Pharmaceutical and Plastics Industry.
NFPA 91 - Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying.
ANSI Z 9.4 - Exhaust System - Abrasive Blasting Operation Ventilation and Safe Practices.
Battelle - Plastic Media Evaluation - A Comparative Study.

SECTION III - EFFECTS OF PLASTIC MEDIA BLASTING

3.1 OVERVIEW

3.1.1 The possibility of damage to structural materials is one of the major concerns in plastic media blasting (PMB) on aerospace systems. A number of research efforts in government and in the aerospace industry have focused on this issue. Specifically, the concerns are about PMB effects on substrates and center around mechanical properties under static and fatigue loading.
Other potential effects under study include changes in airflow characteristics of vehicles due to surface roughening, erosion of cladding or anodized coatings, poor paint adhesion following PMB, and changes in corrosion behavior. Also, surface deformation during PMB could cover fatigue cracks and prevent detection during non-destructive inspection.

3.1.2 The severity of damage to substrate materials depends on the material's characteristics and on the PMB process parameters. Material properties, such as hardness, ductility, and resistance to cracking, contribute to damage levels. Design factors, such as the part's thickness and the layup of composite materials may also effect the potential for severe damage. Process parameters that may influence substrate damage include standard stand-off distance, angle of attack, blasting pressure, dwell time, and the type, size, and hardness of the media.

3.1.3 It is often difficult to determine the amount and seriousness of PMB-induced damage to materials. Effects on mechanical properties may be so small that they cannot be distinguished from normal data scatter. Thus, statistical analysis of data is necessary to provide a high level of confidence that observed effects on properties are not coincidental. Several factors must be considered when evaluating test results:

1. Mechanical testing of materials, particularly fatigue testing, inherently yields scattered data.

2. A component's design and operation influences the criticality of damage induced by PMB. Flight critical or fatigue prone structures may require tighter control of induced effects to authorize PMB use. Liberal allowances may be made for ground equipment or structures with high tolerance to damage.

3. In some cases, the effects of PMB are less damaging than those of alternative paint stripping methods such as hand sanding.

4. The amount of damage to a material depends on the process parameters, the type of material being stripped, and operator technique.

3.2 STANDARD TEST METHODS

3.2.1 Mechanical Properties of Metals

American Society for Testing and Materials (ASTM) E206; Fatigue Testing and the Statistical Analysis of Fatigue Data.
Description: Guide for analyzing fatigue test data.

ASTM E647-86a; Measurement of Fatigue Crack Growth Rates.
Description: Method to determine steady state fatigue crack growth rates using compact type or center cracked tension specimens.

ASTM E466-82; Conducting Constant Amplitude Axial Fatigue Tests of Metallic Materials.
Description: Procedure for performing axial fatigue tests to obtain fatigue strength of metallic materials in the fatigue regime where the strains are predominantly elastic (high cycle fatigue).

3.2.2 Mechanical Properties of Composite Materials.

ASTM D790-84; Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials (Method II: Four-Point Flexural).
Description: Test for flexural strength and modulus of fiber-reinforced composites. The four-point method is recommended since it produces a larger area under uniform, maximum stress than the three-point method.

ASTM D2344-84; Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short Beam Method.
Description: Test for apparent interlaminar shear strength of unidirectional, fiber reinforced composites. Because much of the specimen is under a non-uniform stress state, specimens do not always fail in interlaminar shear, especially when testing high strength composites such as graphite/epoxy. A four-point bend test on a 16-ply specimen with a 16 to 1 span-to-depth ratio is an alternative test that may yield interlaminar failures.

ASTM D3039-76; Tensile Properties of Fiber-Resin Composites.
Description: Test for tensile properties of unidirectional or symmetrical laminates of fiber-reinforced composites.

ASTM D3410; Standard Test Method for Compressive Properties of Unidirectional or Crossply Fiber-resin Composites.
Description: Test for compressive properties in fiber-reinforced composites. Three alternate test fixtures are described. The IITRI fixture is most widely used.

3.2.3 Corrosion Properties.

ASTM B117; Salt Spray (Fog) Testing.
Description: Accelerated test for uniform corrosion.

ASTM G16; Applying Statistics to Analysis of Corrosion Data.
Description: Guide for analyzing corrosion test data.

ASTM G31; Laboratory Immersion Corrosion Testing of Metals.
Description: Accepted procedures for laboratory immersion corrosion tests, particularly mass loss tests.

ASTM G34; Standard Test Method for Exfoliation Corrosion Susceptibility in 2XXX and 7XXX Series Aluminum Alloys (EXCO Test).

Description: Accelerated test for exfoliation corrosion (a form of localized corrosion) in 2XXX and 7XXX series aluminum.

ASTM G46; Standard Recommended Practice for Examination and Evaluation of Pitting Corrosion.

Description: Assistance in selecting procedures for identifying and examining pits and evaluating pit corrosion, a form of localized corrosion.

3.2.4 Paint Adhesion Tests.

FED STD 141, Method 6301; Adhesion (Wet) Tape Test.

Description: Used to determine intercoat and surface adhesion of organic coatings immersed in water.

3.3 EFFECTS ON METAL SUBSTRATES

3.3.1 PMB induces surface residual compression stresses (peening) on metal substrates and surfaces are roughened or eroded. The criticality of stress depends on the type of metal being blasted and its design and use. For aluminum alloys with thickness greater than 0.060 inch, peening does not significantly damage the material's fatigue properties. Depending on the specific metal alloy, temper, and thickness, PMB can significantly change fatigue behavior. These changes will occur if the process is not tightly controlled to minimize damage due to excessive blast pressure, dwell time, or hard contaminants in the media. Thin metal substrates are known to be susceptible to "oil canning" under normal PMB operating parameters. Surface roughening and erosion caused by PMB may damage protective materials such as cladding or anodize coatings. However, changes in surface roughness after PMB have not been shown to effect the aerodynamic efficiency of aircraft. The observations described in the following paragraphs on the effects of PMB taken from the list of studies and reports listed in appendix I.

3.3.2 Surface Damage. PMB can deform surfaces and erode protective anodize coatings and cladding. Several of the studies noted microcracking and removal of sulfuric acid anodize on aluminum, in addition to the erosion of cladding on 7075-T6 aluminum. "Laps" of material on alclad substrates increase the surface roughness after the first blast cycle, but subsequent cycles tend to decrease this roughness by eroding the soft material from the surface. Six to 17 percent of the clad layer was eroded in one study, with isolated areas of 80 percent erosion. In another study, 14 to 20 percent by weight of cadmium plate on steel was eroded. Surface pits, scratches, or defects provide sites for fatigue crack initiation, increasing the chance of an early fatigue failure and provide sites for the initiation of corrosion.

3.3.3 Residual Stress.

3.3.3.1 The impact of plastic beads on a metal surface during PMB induces compressive stress in the surface material similar to the effects of shot peening. Beneath the compressed surface layer a region of tension is formed to balance the compressive stress. Compressing the back of a thin, unconstrained specimen, causes it specimen to bend. This deformation is measured as Almen arc height. In a constrained specimen, this deformation is prevented and the force balance yields a tensile stress at the back surface. These stresses, deforming constrained structures and called "oil canning", result from excessively aggressive PMB process parameters. Compressive stress on the surface may increase fatigue life in some components, while subsurface tensile regions accelerate fatigue crack growth.

3.3.3.2 The amount of residual stress and the depth of the compressive and tensile regions depend on the modulus of the material being blasted, the PMB process parameters, and the number of PMB cycles the material was exposed to. Stress magnitudes can be calculated using arc height measurements of Almen test strips or strain gage measurements on structures. Stress also can be measured using x-ray diffractometry. Battelle researchers measured stress using strain gages on Almen test strips. They recorded a maximum strain of about 250 microstrain, corresponding to about 2.5 thousand psi (ksi) compressive stress. The Oklahoma city ALC study used both Almen strip data and strain gage readings from structural elements to determine induced stress levels and depth of the compressive stress. They calculated compressive stresses of about 20 ksi on the surface of a 2024-T3 aluminum structure, to a depth of 0.0035 inch. The compressive stress on a 7075-T6 panel was about 29 ksi, with a depth of 0.002 inch. Data also indicates that residual stress increases with successive blast cycles, up to a maximum of about four blast cycles. This corresponds to the saturation effect observed in Almen strip testing.

3.3.4 Tensile, Compressive, Flexural Properties. There is no reported evidence of degradation of tensile, compressive, or flexural properties of metals due to PMB.

3.3.5 Fatigue Properties.

3.3.5.1 Introduction. Fatigue is the most common cause of failure of aircraft structural components. In addition, many of the flight critical components are designed using the damage tolerance approach, which relies heavily on knowledge of the fatigue behavior of materials. Thus, any change in fatigue properties could drastically alter the life of the component and the chances of premature failure. PMB affects the regions of a structure at or near the painted surface. Several studies have shown that the process can increase surface roughness of the material, particularly if the material being blasted is relatively soft (i.e., aluminum cladding), and/or the blasting parameters are severe (hard media or media contaminated with hard particles, high blast pressure, or close stand-off distance). Irregularities in the surface can act as sites for fatigue crack initiation. In several PMB studies, hard contaminant particles in the media, such as sand, became imbedded in the surface of the material and initiated cracks that caused a significant decrease in the specimens' fatigue life. These studies emphasized the importance of keeping the blast media free of contamination. As discussed earlier, PMB process-induced residual stresses in the region near the surface of the material are similar to those produced by shot peening. Peening may increase the fatigue life of the material since the surface is in compression, which discourages crack initiation and growth. However, below the surface, there is a region of tension. If a crack is present in this region it will grow faster than a crack in a region with no stress. Thus, researchers have examined both the rate of growth of pre-existing cracks in the structure after PMB (known as fatigue crack growth rate) and the total number of cycles to failure (known as fatigue life). Fatigue life includes both the cycles to initiate the crack and the cycles to cause the crack to grow large enough to cause failure.

3.3.5.2 Fatigue Life.

3.3.5.2.1 Researchers reported no statistically significant reduction in fatigue life of undamaged, unnotched aluminum alloy specimens with thicknesses greater than about 0.06 inches. In fact, some researchers reported an increase in fatigue life after PMB due to surface compressive stress. Some studies indicated a decrease in fatigue life of thinner specimens. In a study performed by Wright Laboratory, particles of sand and hard contaminants were present in the media. These particles imbedded themselves in the material surface and served as fatigue crack initiation sites, thus causing a reduction in fatigue life. Also, this decrease in fatigue life only occurred in specimens blasted at the lower pressure of 38 psi rather than 60 psi, probably because dwell time was longer for the 38 psi experiment, which allowed a greater number of contaminant particles to strike the surface. In addition, fatigue life degradation increased with multiple PMB stripping cycles. Battelle observed similar decreases in fatigue life of aluminum and attributed the decreases to the influence of contaminants. In a follow-on study they used virgin media (not recycled and hence not as heavily contaminated) to blast the specimens and found no significant decrease in fatigue life.

3.3.5.2.2 Specimens with holes, notches, cracks, or flaws were most effected by PMB. A study performed by Oklahoma City ALC Engineering Laboratory reported that PMB reduced the average fatigue life of notched 0.032-inch-thick 2024-T3 aluminum specimens by 66 percent. The fatigue life of 0.040-inch notched specimens of 7075-T6 aluminum decreased 27 percent and 38 percent for nonclad and clad specimens, respectively. The General Dynamics study on F-16 materials also reported a decrease in fatigue life of specimens with drilled holes. A n;umber of researchers reported increases in fatigue crack growth rate (FCGR). The amount of increase varied with several factors, such as specimen thickness, stress intensity factor, blasting pressure, media contamination, and type of alloys. In thin (0.06 inches thick or less) 2024 aluminum alloys, General Dynamics reported increases in FCGR of as much as 10 percent and Oklahoma City ALC reported increases as much as 120 percent. Battelle reported FCGR increases of about 40 percent for 0.016-inch-thick 7075-T6 aluminum specimens blasted with virgin media at 40 psi, while Oklahoma City ALC found no effects on FCGR in the same alloy that was 0.040-inch-thick and subjected to 60 psi blast pressure.

3.3.5.2.3 Summary. In general, PMB effects on fatigue life of undamaged, unnotched components with thicknesses greater than 0.06 inch are negligible. Thinner substrates may suffer a decrease in fatigue life due to PMB, especially if they are subjected to aggressive blasting or exposed to blast media containing hard contaminants. In addition, PMB may accelerate the growth of any flaws, holes, or large cracks in the material. To reduce damage to fatigue properties, PMB process parameters must be chosen to induce the least amount of stress possible in the surface of the material. Higher peening stresses are related to an increase in fatigue crack growth rate.

3.3.6 Corrosion Properties. Research by the NAVAIR Engineering Support Office at Naval Aviation Depot, Pensacola, FL, and the Air Force Corrosion Program Office indicates that PMB does not adversely affect corrosion rates in bare aluminum alloys (7075 and 2024 series). However, there is evidence in both studies that PMB causes cracks in anodize coatings and removes or damages cladding. This damage, which changes the material's corrosion behavior, may cause future corrosion problems if protective coatings are not re-applied. In addition, the NAVAIR study showed that PMB caused pinhole penetration of cadmium plating on steel, which led to increased corrosion.

3.4 EFFECTS REPORTED BY PUGET SOUND NAVAL SHIPYARD ON "HEAVY IRON" APPLICATIONS

3.4.1 Background. Puget Sound Naval Shipyard received funding from the Naval Energy and Environmental Support Activity to install a PMB system. A system was installed for use on small parts that would normally be stripped in the shipyard's 2,000-gallon methylene chloride paint strip tank. The system includes a 10x10x15-foot blast enclosure, two blast pots with 6-cubic-ft capacity, and media classification equipment (cyclone separator, magnetic particle separator, and vibratory deck). The system recovers media by vacuuming it through hoses connected to vacuum ports in the side of the booth. The shipyard's goal is to use PMB on half of the workload normally processed in the methylene chloride tank.

3.4.2 Materials and parameters. Using type II media exclusively, the shipyard removed such coatings as epoxy paint (MIL-P-24441), chlorinated enamel with primer (MIL-E-17970/71/72 & TT-P-645 primer), epoxy powder coating (International AL106U), and polyester powder coating (Fuller Obrien PFY-500 S8). The standard equipment settings were: media feed rate of approximately 600 lbs per hour, nozzle pressure of 40 to 55 psi, nozzle size of 1/2 inch, angle of attack of 60 to 90 degrees from the work piece, and a standoff distance of 6 inches. The parameters are aggressive and provide good removal rates for those items not subject to damage. The pressures, angles of attack, and standoff distances were modified when blasting more sensitive items. Substrate materials that coatings were removed from for the evaluations included iron and steel (shackles, deckplates, various castings), aluminum (antennae, wave guides, doors, aircraft chairs), and brass and bronze (castings).

3.4.3 Effects. The shipyard experienced no damage to those substrate materials blasted with type II media, including thin-skinned antennae and wave guides. However, a film left on the wave guides after blasting created problems during subsequent iridite treatments. The film acted like a mask causing the wave guides to appear spotty.

3.5 EFFECTS ON COMPOSITE SUBSTRATES

3.5.1 Introduction.

3.5.1.1 Composite materials currently used in aircraft are composed of continuous high strength fibers bound together by a relatively low polymeric resin. Since the fibers are aligned unidirectionally within a ply, the mechanical properties of that ply are anisotropic. The material is much stronger in the direction parallel to the fibers than in the direction perpendicular to the fibers. In most composite structures the piles are stacked on one another in various orientations to make the properties of the material more isotropic. However, some of the properties of the material are limited by the strength and integrity of the fibers (fiber dominated properties), while others depend on the properties of the matrix material (matrix dominated properties). For example, tensile properties are typically fiber dominated, whereas, compressive and interlaminar properties are matrix dominated. The matrix also controls the resistance of the material to environmental influences such as moisture, solvents, and heat.

3.5.1.2 PMB tends to erode the surface of composite materials. Since the matrix often is brittle material, such as epoxy, which has the same hardness as the paint coating being removed, it may be eroded or cracked by the impacting media beads. If significant amounts of the matrix are eroded or the matrix is cracked, the matrix dominated properties of the material may suffer. Very small cracks (microcracks), which can affect the matrix dominated properties, are difficult to detect with non-destructive inspection (NDI). In extreme cases PMB also damages the fibers. This can cause degradation of fiber dominated properties, especially if the damage is extensive through one or more plies. Disbonds (separation of the fiber/matrix interface) also cause degradation in matrix dominated properties. Composites also are subject to subsurface impact damage, such as delaminations, which occur when adjacent plies separate from one another. Delaminations can grow under applied stress until the material peels apart.

3.5.1.3 The results of experiments using PMB on composites indicate that blasting parameters must be less severe than those on metal substrates and must be carefully controlled to prevent damage. The relationship between several PMB factors and damage in composites has been demonstrated in a number of studies. These factors include dwell time, stopping the stripping at the primer level, media hardness, blasting angle, pressure, and standoff distance.

3.5.2 Surface Damage.

3.5.2.1 The most direct method of subjectively determining the amount of damage to a composite material is to examine the surface using optical microscopy or scanning electron microscopy (SEM) or by examining the bulk of the material for cracks and delaminations using NDI techniques, such as ultrasound and x-ray. Degradation in mechanical properties due to the blasting process is linked to the observed amount and type of damage done to the material.

3.5.2.2 All of the studies reported surface damage to varying degrees depending on the process parameters used. The Naval Air Development Center study revealed extensive surface damage. Severe fiber damage was observed after an extended dwell (five times the dwell necessary for paint removal) using type II (3.5M) media at a pressure of 35 psi and a blast angle of 45 degrees from vertical. The Wright Laboratory study also produced extensive fiber damage (up to 10 fiber diameters deep) after 4 PMB cycles at 60 psi with type II media. General Dynamics evaluated PMB effects on a thin graphite/epoxy composite component with a fiberglass scrim ply to determine if the process was suitable for the F-16. They were stripped six times with type II media at 35 psi at a 40-degree angle. Erosion extended through the scrim ply and into the topmost fibers of the underlying composite. Some studies reported evidence of matrix microcracking in the resin-rich area near the surface of the composite. Most studies reported erosion of the surface gel coat and little, or no, fiber damage on the first strip cycle. Repeated cycles produced further erosion. When stripping was stopped at the primer layer, no significant surface damage was found, even after four PMB cycles. In composites containing Kevlar fibers, "fuzzing" of the fibers was evident in a Navy study on PMB paint removal on the AV-8B aircraft. These fibers were used as stitching on the composite's surface, and the damage did not effect the structural properties of the material. The technicians, who were instructed to strip only to the primer layer, noted very little damage to graphite fibers or the epoxy matrix.

3.5.3 Subsurface Damage. NDI techniques, such as ultrasound or x-ray, and microscopic examination of a cross section of the material can detect subsurface damage in composites, such as delamination (separation of adjacent plies), disbonds (separation at the fiber/matrix interface), and cracking. This type of damage can be very dangerous in a composite component. Since it cannot always be detected by visual inspection of the surface, subsurface damage could degrade mechanical properties. Under any process conditions plastic bead blasting did not cause damage below the surface plies in any of the studies. NDI methods also were used to examine honeycomb core structures with composite skins that were subjected to PMB. No disbonds were observed between the core and skin materials.

3.5.4 Tensile and Flexural Properties. None of the studies indicated significant PMB induced degradation in fiber dominated properties (tensile and flexural strength and modulus parallel to the fiber direction) in unidirectional laminates. Matrix dominated properties, such as unidirectional tensile and flexural strength in a direction perpendicular to the fibers, were more scattered after PMB in the Wright Laboratory study, although no statistically significant average degradation was noted. Statistically significant decreases in 90-degree unidirectional flexural strength were noted in the Wright Laboratory study, as well as wider scatter in the data. This was seen as evidence that microcracking was occurring in the matrix material. The mechanical properties of quasi-isotropic (QI) laminates do not display as much degradation due to PMB, since their properties are not purely matrix or fiber dominated, as in the unidirectional composites. However, Wright Laboratory researchers noted decreases in flexural strength of QI laminates with 90-degree surface plies.

3.5.5 Compressive Properties. PMB caused degradation of compression strength in some cases, when high pressures (60 psi) and relatively hard media were used. Wright Laboratory and Oklahoma City ALC reported a slight decrease in unidirectional compressive strength when they blasted specimens with type I media at 60 psi. Compression strength is a matrix dominated property.

3.5.6 Interlaminar Shear Strength. Significant decreases in interlaminar shear strength (ILSS) were observed for unidirectional and QI specimens when blast pressures were 60 psi or greater. ILSS is a matrix dominated property.

3.5.7 Fatigue Properties. The General Dynamics F-16 study examined PMB effects on fatigue properties of composites. The researchers found no evidence of significant fatigue life reduction or increase in fatigue crack growth rate after blasting a thin graphite/epoxy laminate based on the design of the F-16 horizontal stabilizer. However, because of the complex nature of testing composites for fatigue, these results cannot be viewed as conclusive for all materials and layups.

3.5.8. Summary. PMB paint stripping causes surface erosion in composites unless the material is stripped only to the primer layer. Erosion of the composite's gel coat (resin-rich surface) does not degrade mechanical properties, if severe damage to underlying fibers or matrix microcracking is not induced. Composites require less aggressive blast parameters than metal and strict operator control of the PMB process to prevent substrate damage.

3.6 EFFECTS OF PMB ON COMPOSITES (NAVY)

3.6.1 Naval Air Warfare Center, Aircraft Division, Warminster PA, in coordination with Naval Air Systems Command, Washington DC, developed a four-phase test program to determine the effects of PMB on advanced composite substrates used on Navy aircraft. The first two phases deal with microstructural evaluation and flexural testing of PMB on advanced composites used for primary structures. The third and fourth phases deal with extensive mechanical property evaluations of both primary and secondary structures. Phases I, IIa, and IIb of the test program are complete. Phase I identified optimum PMB operating parameters, operator dependent and non dependent. Phase IIa consisted of optical and scanning electron microscopy evaluation of test panels subjected to PMB at various operator dependent parameters. Phase IIa also had test panels subjected to jitter-bug sanding (currently the only allowable paint removal technique). Phase IIb consisted of mechanical testing, specifically four-point flexural testing, of panels blasted at dwell times that initiate fiber damage as identified in phase IIa. Phase III will expand the mechanical testing done in phase IIb to include several of the most severe conditions on actual aircraft composite configurations. This will include tension, compression, and full-spectrum fatigue testing of specimens as well as those stripped by jitter-bug sanding. Phase IV will be an assessment of PMB on secondary composite structures. This will include other polymer matrix materials, other reinforcements, composites used for lightning strike protection, etc. Phase IV work, which primarily will consist of microscopy studies, will be formulated based on Phase I-III test results. PMB effects on honeycomb core materials are being evaluated under a separate test program.

3.6.2 AS4/3501-6 graphite/epoxy samples are used in phase I-III because it is the most common composite material for structural applications on existing Navy aircraft. Other composite materials commonly used in secondary structure applications will be investigated during phase IV. As indicated by the phase IIa results shown below, no significant fiber degradation was achieved until ten to fifteen blast cycles.

PHASE IIa (MICROSCOPY) RESULTS

Stand-off Distance	Blast Angle	Paint Removal Dwell time	Category
6"	90 degrees	5 cycles	1
		10 cycles	2
		15 cycles	2
		20 cycles	3
6"	45 degrees	5 cycles	1
	(0 degrees to fiber)	10 cycles	2-3
		15 cycles	3
		20 cycles	4
6"	45 degrees	5 cycles	2
	(90 degrees to fiber)	10 cycles	3
		15 cycles	3
		20 cycles	3
12"	90 degrees	10 cycles	1
		15 cycles	2
		20 cycles	3
		25 cycles	3
12"	45 degrees	10 cycles	2
	(0 degrees to fiber)	15 cycles	3
		20 cycles	3
		25 cycles	3
12"	45 degrees	10 cycles	2
	(90 degrees to fiber)	15 cycles	2-3
		20 cycles	3
		25 cycles	3

Category codes:

0 - control material, no sign of damage;
1 - minor surface abrasion, release ply pattern is clearly visible, no damage;
2 - extensive resin abrasion, release ply pattern is visible, minor fiber damage;
3 - release ply pattern is no longer visible, extensive fiber damage;
4 - damage extends into the second ply.

As indicated by the phase IIb results below, there is no reduction in strength for any of the blasting parameter combinations.

PHASE IIb PRELIMINARY RESULTS

Panel #	Cycles of Dwell	Stand-off Distance	Angle of Attack	Orientation to Fibers	Strength Change?
1D	Paint Removal	12"	45 deg.	90 deg.	NO
10A	Paint Removal	12"	90 deg.	n/a	Increase
13B	Paint Removal	12"	45 deg.	0 deg.	Increase
10B	Paint Removal	6"	90 deg.	n/a	NO
13D	Paint Removal	6"	45 deg.	0 deg.	NO
13E	Paint Removal	6"	45 deg.	90 deg	Increase
1E	10 X Removal	12"	45 deg.	90 deg.	Increase
5A	10 X Removal	12"	90 deg.	n/a	NO
6E	10 X Removal	12"	45 deg.	0 deg.	Increase
6A	10 X Removal	6"	90 deg.	n/a	Increase
6B	10 X Removal	6"	45 deg.	0 deg.	Increase
6D	10 X Removal	6"	45 deg.	90 deg	Increase
5E	20 X Removal	12"	90 deg.	n/a	Increase
10D	20 X Removal	12"	45 deg.	0 deg.	Increase
5D	20 X Removal	6"	90 deg.	n/a	Increase
10E	20 X Removal	6"	45 deg.	0 deg.	Increase
5B	20 X Removal	6"	45 deg.	90 deg.	Increase
1A	Paint Removal	Sanded w/80 grit orbital sander			Increase
1B	2 X Removal	Sanded w/80 grit orbital sander			Increase

A statistically significant (at 95% confidence level) increase in flexural strength was found for approximately 75% of the test panels. Possible reasons for the increase in flexural strength are:

1. Erosion of the non-structural gel coat effectively increases the percentage of the cross-sectional area that can carry load. This reduced total cross section is able to take the same loading levels as the unblasted specimens. The area the load is divided by is less; therefore, the strength of the specimens is greater.

2. The blasting and subsequent removal of the gel coat relieves the specimens' stress.

3. A combination of 1. and 2.

SECTION IV - PRACTICES

4.1 GENERAL

4.1.1 Material Specification, MIL-P-85891, developed by the Navy for plastic abrasive blasting, is approved for use by the Department of Defense. All maintenance organizations reference the specification in their paint stripping process specifications and procurements. MIL-P-85891 briefly covers the six types of plastic media described in section II of this document. MIL-P-85891 is the authorizing document for procuring, or developing process specifications. Address comments (recommendations, additions, deletions) and data that may be of use in improving MIL-P-85891 to: Systems Engineering and Standardization Department (Code 53), Naval Air Engineering Center, Lakehurst, NJ 08733-5100.

4.1.2 PMB specifications on paint removal generally are similar in blasting media and parameters authorized for use among the various military departments. Aero Almen Strip tests are used to verify process parameters and techniques. The almen strip tests also allow optimization of nozzles, media selection, and process modification, while maintaining the same level of peening effect on substrates. Each of the Services has developed process specifications for aircraft application. The Air Force has Technical Order 1-1-8, "Application Of Organic Coatings, Aerospace Equipment." The Army's aircraft stripping is approved at various commercial facilities and at the Army Helicopter Repair Center at Corpus Christi, TX. The Navy PMB specification, authorizing general use, was issued in Jun 91 by Naval Air Systems Command.

4.2 AIR FORCE GENERAL TECH ORDER 1-1-8

4.2.1 Introduction. The Air Force Corrosion Control Board located at Warner Robins Air Logistics Center, GA, approves general processes for applying and removing coatings from aerospace hardware. Technology demonstrations and development tests validating the use of paint removal systems are funded and conducted by the various maintenance depots, Wright Laboratory, the Corrosion Control Board, developers of new paint removal technologies, and through contracts with airframe manufacturers and independent testing laboratories. Once a coating removal method has been scrutinized for general materials effects on typical aircraft substrates, the process may be deemed appropriate for use. The authorization for use is then granted, contingent upon approval by the specific weapon system engineering evaluation group. For instance, the PMB process is now approved for general use on metal and composite substrates. However, to use the PMB process on an F-16 aircraft, the F-16 systems manager also must perform pertinent tests to determine if PMB can be used on F-16-specific metal and composite structures. Once this testing is completed, the aircraft-specific T.O. 1F-16A-23 (for paint removal) will be modified to permit PMB use. Methods not authorized by T.O. 1-1-8 may only be used in maintenance organizations on a local engineering evaluation basis for limited applications. Unauthorized processes are not sanctioned until sufficient testing has validated the suitability of the methods for general use. Coordination with engineers from the Corrosion Board to determine appropriate validation tests and to discover previous test results is highly encouraged for any new paint removal technology.

4.2.2 Mechanical Removal of Organic Finish Systems. Mechanical coatings removal is recommended when use of chemical removers is impractical due to structural complexities and/or local environmental restrictions. Mechanical removal methods include the use of hand held brushes, bonded abrasive papers or cloths, and abrasive mats; motor driven wire brushes, bonded abrasive paper or cloth discs, and abrasive mat discs and flap brushes; and abrasive blasting. While these methods are very effective for finish system removal, they can cause severe damage to structure and equipment in a very short time if improperly used. Therefore, mechanical removal of finish systems must be used only when specifically authorized and approved by the responsible ALC aircraft system program manager (SPM) or equipment/component item manager with full knowledge of, and in conjunction with, the ALC corrosion program manager. In addition, mechanical removal methods must be restricted to only those areas for which they have been approved, and must be performed as directed by the instructions in the T.O. The following warnings apply:

1. Abrasive blasting, motor driven wire brushes, and motor driven abrasive operations create airborne particles that are hazardous to the eyes and the body.

2. The dust created by either of these methods is hazardous to the respiratory tract, and noise produced by abrasive blasting is hazardous to the hearing. Personnel performing either of these removal methods must wear coveralls with full-length sleeves and gloves with gauntlets. Personnel using motor driven abrasive must wear dust/particulate type face masks, goggles, and/or full face shields. Personnel performing abrasive blasting must wear an abrasive blasting airline/hood respirator and hearing protection meeting the requirements of AFOSH STD 161-1. Contact the base bio-environmental engineer for specifics on required protective equipment.

3. Dust generated from abrasive, metal, and finish system particles during abrasive blasting, motor driven wire brush, or motor driven abrasive disc finish removal operations creates the potential for a dust explosion. Use only pneumatic type motor driven equipment. Electrically ground all motor driven equipment, abrasive blasting equipment, work stands, and work pieces properly. Avoid all sources of ignition where these operations are in progress, and adequately ventilate the area.

4. Abrasive blasting, motor driven wire brush, or motor driven abrasive disc finish system removal on steel and titanium alloy surfaces may cause sparking. Perform these operations in a well ventilated area, and take proper fire safety precautions. If these methods are being used in a large operation involving other types of metals, remove the finish system from the steel and titanium surfaces first; and then proceed to the other areas.

5. Low carbon steel brushes must not be used on aluminum, magnesium, copper, stainless steel, or titanium alloy surfaces as steel particles will embed in these surfaces and later rust or cause galvanic corrosion of these surfaces. Copper, brass, or beryllium copper brushes must not be used on aluminum, magnesium, steel, stainless steel, or titanium alloy surfaces as they will smear on these surfaces and cause galvanic corrosion.

6. Mechanical methods must be used only long enough to remove the finish system and not abrade the underlying metal surface. Speed of removal is not the most important factor. Removal without damage to the metal surface, without creating a condition that can lead to future corrosion damage to the metal surface, and providing a surface suitable for finish system reapplication are the most important factors.

7. When using mechanical methods, abrasive blast media and pieces of broken brushes and discs can escape from the work area. These methods must not be used in areas or under conditions that allow escaped particles to enter into and damage or contaminate any system, engine, or other component. Barriers must be erected around the work area and/or masking of the surrounding area. All holes leading to the interior of systems and equipment must be masked to prevent damage to, and contamination of, systems and equipment by dust, abrasive blast media, and pieces of broken brushes and discs. Consult the system peculiar aircraft corrosion manual or the specific equipment manual for proper masking for removing system's mechanical finish.

8. Leave protective clothing worn during abrasive blasting in the work area. Do not take them home for cleaning.

4.2.3 Finish System Removal by PMB.

4.2.3.1 PMB is an excellent and rapid method for removing a system's finish, but it can severely damage the structure and injure personnel, if not done properly, with the right type of equipment, in the right type of facility. In addition, proper waste management must be ensured for economic and environmental reasons. Therefore, PMB is authorized at depot and field level operations contingent upon SPM approval of facilities, personnel training, and processes as specified in weapon system specific technical data. The T.O. instructions are not all inclusive, but are general mandatory guidelines to be used with additional instructions in applicable aircraft or equipment manuals. All PMB finish removal operations shall conform to the T.O. 1-1-8 requirements.

4.2.3.2 Media type. Media shall be fabricated from plastic stocks that are free from high-density particle contamination and other impurities. Use plastics of a specific, non-changing chemical composition as specified in MIL-P-85891 and in T.O. 1-1-8. PMB media shall have a particle size of U.S. screen 20 to 40 mesh; however, 12 to 16 mesh may be added as make-up media. The media shall have an irregular particle shape with sharp, angular edges and corners. Plastic media are classified by type that specifies the hardness of the plastic and, therefore, the performance characteristics. MIL-P-85891 defines the media types and section II of this document describes them.

4.2.3.3 Media authorized for Air Force use. Plastic media meeting the specific definitions of MIL-P-85891 can vary from manufacturer to manufacturer. The media of authorized sources have undergone tests to meet the Air Force requirements. The Air Force maintains a list of approved sources by media type and manufacturer for procurement purposes. Media conforming to the first article requirements of MIL-P-85891 also are authorized for use.

4.2.3.4 Media Contamination Level. Media having a high-density particle contamination may decrease the fatigue life of fatigue critical, thin skin materials that are stripped using PMB. Fatigue sensitive aluminum and magnesium alloys less than .060 inches thick are susceptible to this type of degradation. Therefore, media not meeting the high density contamination levels outlined in T.O. 1-1-8 will not be used on Air Force equipment and must be purged from blasting equipment and replaced with media conforming to the T.O.'s requirements. Many types of high density contaminants can be introduced into the blast media during manufacture and use. The major types of contaminants are sand, glass, and other silicate based materials; aluminum, magnesium, iron, and zinc based metals; paints and sealants; and high-density plastics.

4.2.3.5 As different contaminants affect the fatigue life in varying ways, it is difficult to list an overall high-density particle contamination level that is not too restrictive of the entire process. Therefore, the contamination level test procedures are a culmination of tests that will allow the user to identify the quantity and class of contaminants. Prior to use, each batch/lot or composite mixture of several batches/lots of new media shall be sampled and tested for contamination level. The tests shall also be performed after every 80 hours of equipment operation time or after each aircraft or large piece of aerospace equipment is blasted (whichever is longer). Non-aerospace equipment, such as aviation ground equipment (AGE) and vehicles, is less sensitive to media contamination. Therefore, media used to strip these items should be tested for contamination after every 800 hours of equipment operation. Media with high-density particle contamination level greater than what is stated in T.O. 1-1-8 shall be purged from the system and replaced with new media. Testing shall be conducted by the depot's quality laboratory IAW the level determination procedures provided in T.O. 1-1-8. The T.O. describes the equipment/materials required, sampling procedures for used media from the blast facility or new media, and contamination test procedures.

4.2.3.6 Operational Parameters for Metallic Surfaces. All PMB operations for use on metallic surfaces shall conform to the following parameters.

1. Pressure shall be within 40 to 60 psi at the blast nozzle for 3.0 Moh hardness media (type I), 25 to 40 psi at the nozzle for 3.2 Moh hardness media (type V), and 20 to 30 psi at the nozzle for 3.5 Moh hardness media (type II). T.O. 1-1-8, paragraph 2.16.a recommends parameters for stripping AGE and vehicles.

2. The blast nozzle tip to work surface stand-off distance shall be within 12 to 24 inches for 3.0 Moh hardness media (type I), 12 to 24 inches for 3.2 Moh hardness media (type V), and 18 to 30 inches for 3.5 Moh hardness media (type II). T.O. 1-1-8, paragraph 2.16.a recommends parameters for stripping AGE and vehicles.

3. The angle of incidence between the blast nozzle and the work surface shall be within 30 to 90 degrees for 3.0 Moh (type I), and 3.2 Moh hardness media (type V), and from 0 to 60 degrees for 3.5 Moh hardness media (type II). AGE and vehicles may be stripped at any angle.

4. PMB shall not be used on metal structures less than 0.016 inches thick for 3.0 Moh and 3.2 Moh hardness media (type I and V) and 0.032 inches for 3.5 Moh hardness media. Paragraph 2.16.a of T.O. 1-1-8 gives restrictions pertaining to AGE and vehicles.

4.2.3.7 Operational Parameters for Non-metallic (Composite) Surfaces. All PMB operations for use on non-metallic surfaces (fiber-glass, kevlar/epoxy, graphite/epoxy, etc.) shall conform to the following parameters.

1. Pressure shall be within 30 to 60 psi at a blast nozzle for the 3.0 Moh hardness media (type I), and within 25 to 40 for the 3.5 Moh hardness media (types II and V).

2. The blast nozzle tip to work surface stand-off shall be within 12 to 24 inches.

3. The angle of incidence between the blast nozzle and the work surface shall be within 40 to 60 degrees (measured from the horizontal).

4. To maintain a constant removal rate and limit the amount of time the PMB blast impinges on any given surface (dwell time), pressure should increase as the stand-off distance increases or as the angle of incidence decreases.

4.2.3.8 Operational Safety Requirements.

1. Keep all ignition sources at least 50 ft away from the blasting area.

2. Electrically ground all blasting equipment, work stands, aircraft equipment, and components per T.O. 00-25-172 and the applicable aircraft or equipment manual during the entire PMB operation.

3. Remove all power from the aircraft or equipment during PMB.

4. Titanium and steel alloy surfaces will spark when subjected to PMB. When PMB involves a combination of these and other metals, blast the titanium and steel alloy surfaces first.

5. The PMB facility shall have adequate air flow/ventilation to prevent build up of an explosive dust mixture. Consult the base environmental engineer for proper ventilation requirements.

6. Personnel involved in PMB shall wear coveralls with full-length sleeves, gloves with gauntlets, full air supplied respirator type hoods, and hearing protection that meet AFOSH STD 161-1 and AFR 161-35 requirements. Blasters shall put on hoods before entering the blasting area and not remove them until after leaving the blasting area. Blasters must store hoods in a clean dust free area and shall clean the hoods to remove all dust accumulations. All personnel entering the blasting area while PMB is in progress, even if they are not involved in the operation, shall comply with these personnel protection requirements. Protective clothing worn during PMB shall remain in the work area and not taken home.

7. Blast nozzle operators shall never direct a nozzle at other personnel. If more than one blast nozzle operator is involved in an operation at the same time, they shall be located on opposite sides and/or ends of the aircraft or equipment being blasted to ensure safe separation.

8. Dust and media residue generated during PMB create very slippery conditions. Walking on top of aircraft or equipment during PMB shall be avoided, if possible, or shall be done with extreme caution by personnel wearing fall protection devices, if it is absolutely required. All work stands shall be equipped with guard rails to prevent falls.

4.2.3.9 Personnel Qualifications. Only thoroughly trained personnel shall perform PMB. This training shall include familiarity with the PMB requirements and techniques specified in T.O. 1-1-8 and applicable system peculiar aircraft or equipment technical orders.

4.2.3.10 Preblast Preparation.

1. Clean the aircraft, equipment, or component per T.O. 1-1-691 to remove all grease, oil, hydraulic fluid, and dirt from surfaces before masking them for blasting. Stop all fluid leaks and allow surfaces to fully dry before masking and putting the item into the blasting facility. Water and other fluids contaminate blasting media and may damage separation equipment.

2. Mask the aircraft, equipment, or component before beginning PMB to prevent blast media and dust from penetrating those areas that are susceptible to damage or contamination by media impingement. Masking shall be accomplished IAW instructions in T.O. 1-1-8 and the applicable system peculiar aircraft or equipment T.O. or corrosion manual.

4.2.3.11 Postblast Cleaning. After the finish system has been completely removed from the aircraft, equipment or component by PMB, all surfaces shall be thoroughly vacuumed with a heavy duty, pneumatic type, wet/dry vacuum cleaner. An alternative is to use compressed air or water wash to remove dust and media residue. All areas that were masked or plugged shall be inspected for the presence of dust and media particles as the masking and plugs are removed and vacuumed clean as necessary.

4.2.3.12 Specific Technical Data and Work Directives. Each aircraft system program manager or equipment item manager shall prepare detailed masking and blasting instructions that conform to the requirements in T.O. 1-1-8. The managers shall incorporate the instructions in the applicable aircraft or equipment T.O. and corrosion manual before beginning blasting operations. In addition, for each separate PMB operation, a detailed work specification/project directive shall be prepared that levies a requirement IAW the technical data on their maintenance organization or contractor. A detailed step by step process order or work control document that complies with all the technical data and work specification/project directive requirements shall be prepared by the maintenance organization or contractor for each separate PMB operation.

4.3 ARMY AVIATION COMMAND TECHNICAL ORDER

4.3.1 Introduction. The Army uses a variety of plastic, organic, and mineral media in its abrasive media blast facilities to routinely strip shipping containers, ground vehicles, equipment, and other non-aircraft components. The Army has approved the use of PM for aircraft stripping at various commercial facilities and at the Corpus Christi Army Depot (CCAD), Corpus Christi, TX. CCAD developed the specification for general use on all Army helicopters; "General Specification for Removal of Organic Coatings from Army Aircraft Using Plastic Media Blasting." This specification provides requirements and procedures for using PMB and covers depot or contractual use. The specification applies to open blasting only and shall only be used on metal and fiberglass (honeycomb and matrix-backed), carbon fiber, boron, and graphite/epoxy composite surfaces. The specification procedures do not apply to kevlar materials or engineered plastics whose design requirements specify that they must remain transparent/translucent.

4.3.2 Material Requirements. The PM type used in the Army's blasting operations on aircraft shall be manufactured from a virgin acrylic plastic IAW the requirements stated for Type V, Grade A, PM in MIL-P-85891. The particle shape of the acrylic media shall be irregular with sharp, angular edges and corners, and should have a hardness of 46 to 54 BARCOL. The media particle size shall be 20 to 30 mesh. If the minimum stripping rate of 0.50 sq ft/min cannot be met, an additive of 16 to 20 mesh media is authorized as long as a maximum arc height of less than 10 mils is maintained. The media's chemical and physical properties shall be IAW Table I of MIL-P-85891.

4.3.3 Equipment requirements. The Army's PMB equipment for aircraft use shall be a direct pressure-feed unit capable of propelling a controlled and continuous stream of PM. Indicators and regulator devices are required for the equipment. Do not use siphon-fed equipment. The blasting equipment shall have a media classification system designed with a recovery system consisting of:

1. A cyclone separator to separate dust from PM.

2. A rotary airlock to pass heavier PM through rotary vanes into a magnetic separator.

3. A magnetic separator to remove ferrous material impurities from the PM.

4. A vibrating screen separator to separate undersized media from heavier media.

5. A double chamber pressure pot shall be used to maintain a continuous media stream.

4.3.4 Maintenance and Operator Equipment. The Army's equipment for PMB cleaning and paint removal shall be operated and maintained IAW equipment manufacturer's instruction manuals. Blasting nozzles and PM transport hoses shall be inspected (at least twice a week) for excessive wear and, as required, worn items replaced. The following operator safety equipment is required:

1. Breathing air filters that accommodate four air fed helmets (Model CPF-80, Clemco Industries or equivalent).

2. Breathing air monitors that monitor carbon monoxide (Model ABL-SO, Dynamation Inc. or equivalent).

3. Radio headset for voice communications.

4. Hearing protection as required by operator safety regulations.

5. Blast suit with helmet and gloves ("Apollo" helmet with leather front, Clemco Industries or equivalent).

4.3.5 Facility Requirements. Army PMB facilities shall have ventilation systems capable of providing a minimum cross-draft ventilation of 75 cubic ft/min and a digital dust concentration monitor and dust collector (Farr Company, aspirated cartridge with reverse pulse jet cleaning or equivalent). An illumination of 150 foot candles is required of the lighting systems and additional portable lighting with multiple positioning should be provided; Rig-A-Lite or equivalent. The compressed air used in the facility shall be trapped and filtered to remove moisture, oil, and solid particles. The following is a list of facility safety requirements:

1. A flashing safety warning light, located outside the enclosure, shall operate during the blasting cycle.

2. All doors shall open from both sides and have a safety device to stop the blasting equipment when a door is opened.

3. All electrical equipment shall meet requirements of the National Electrical Code Class II for the areas where they are located, i.e., for motors, lighting, and outlets.

4. Utilities associated with installation shall meet the requirements identified in Article 513 of the 1984 National Electrical Code.

5. Static straps/grounding cords and grounding points are required in the PMB; per T.O 00-25-172. Caution: Ground sensitive electronic/avionics equipment to preclude electrical static discharge (ESD) damage.

6. A closed-head, wet/dry automatic sprinkler system that complies with OSHA 1910.150 and NFPA 13,Vol. I is required in each room and enclosure.

7. Operators, maintenance personnel, and equipment shall be protected from shock and moving machine parts.

8. Integrated emergency lighting is required in the facility to illuminate the exit way in case of a power failure.

9. Illuminated exit signs are required inside the facility.

10. A digital dust concentration monitoring system is required for the PMB system. The air flow should be continuously monitored to ensure that the airborne concentrations do not exceed 15% of the minimum explosive dust level; Section 6.6 of MIL-P-85891.

4.3.6 Training Requirements. Personnel performing and supervising the PMB removal of organic coatings (lacquers, primers, and top coats) from aircraft and component parts shall complete a three-phase certification program. The Aviation Troop Command's (ATCOM) Director of Maintenance shall designate the source of PMB training. Phase I shall consist of lectures and demonstrations that include examinations enough to assess the candidate's comprehension of the subject matter. Training shall include but not be limited to the following topics:

1. A general knowledge of abrasive stripping with plastic media, and media characteristics.

2. A general knowledge of the facility and media cleanliness requirements cited in the Army specification and an understanding of their importance.

3. A thorough understanding of the contents of the Army specifications as they relate to PMB parameters and applicable substrates.

4. A specific knowledge of the aircraft surfaces, parts, and coating systems to be removed.

5. A specific knowledge of pre-operation cleaning and inspection requirements.

6. A specific knowledge of masking techniques and materials required to prevent PM intrusion during PMB operations.

7. A knowledge of personal protection equipment requirements and the proper use of this equipment.

Phase II shall consist of actual PMB equipment use on test panels and scrap aircraft parts and be approximately 40 hours. Phase III shall consist of apprentice training for at least one week. New operators will be supervised by previously certified personnel or instructors during PMB of actual production aircraft parts and components or surfaces.

4.3.7 PMB of Organic Coating Systems.

4.3.7.1 Media Contamination. Media having a high density particle contamination level of 250 to 300 parts per million (ppm) can cause structural fatigue, and are not permitted for airframe substrates. Test media as a first article, and as required thereafter, per the army's specified requirements to maintain an acceptable levels of contamination. Purge media with an unacceptable level of contamination from the system and replace with new media. To sample the media collect approximately two liters of media from either the blast facility or from the new media for a sample. The best representative media sample comes from the blast nozzle. If this is not feasible, collect the sample from the hoppers. Obtain the best representative sample of new media by agitating the shipping container to thoroughly mix media.

4.3.7.2 Media Contamination Test Procedures.

1. Equipment/materials required:

- 500 milliliter (ml) separatory funnel
- one liter of freon 113
- glass funnel approximately 3 inches in diameter
- number 42 filter paper to fit glass funnel
- scales with 1000 + 0.0001 gm capability
- 500 ml beaker

2. Make sure all glassware is clean and dry.

3. Add approximately 300-350 ml (bulk dry volume) of sample media to the 500-ml beaker.

4. Weigh the beaker and media (+0.01 gm) and record (weight #1) gross weight.

5. Pour the media into the 500-ml separatory funnel (stopcock closed) and make sure there is no spillage. Then obtain the empty weight (+0.01 gm) of the 500-ml beaker (record weight #2).

6. Add the freon 113 to the separatory funnel and note that the media will begin to float. Leave approximately 1/4 to 1/2 inch of air space in the separatory funnel for ease of agitation.

7. Agitate the media/freon 113 and notice that high-density particles will begin to separate. A swirling motion is more appropriate than shaking, as shaking may entrain high-density particles back into the media from which they have been separated. Used media samples contain some dust, which may be suspended in the freon 113 after agitation. Allow three hours for suspended dust to settle or float.

8. Place the number 42 filter paper in the funnel. The high-density particles will settle out in the bottom of the separatory funnel (on top of the stopcock). Use short duration opening of the stopcock to drain high-density particles into the filter funnel. Tapping the side of the separatory funnel may help to remove the high-density particles. Do not allow the freon 113 level to get too low; this may allow some floating media to be deposited with the high-density contaminants. If required, add additional freon to the separatory funnel, using care not to agitate the mixture. If agitation occurs, allow three hours for suspended dust particles to float/settle before continuating decantation.

9. Allow the filter paper with contaminants to dry in a desiccant chamber for at least one hour. Measure the weight of the filter paper and contaminants (+/- 0.0001 gm) and record. Allow the filter paper to dry an additional 30 minutes and reweigh the filter paper and contaminants (+/- 0.0001gm), and compare with the weights measured above. If there is a change greater than 0.001 gm, continue to allow the sample to dry. Once the gross weigh of the filter paper and contaminants has been determined and recorded (weight #3), remove and save the contaminants from the filter paper by tapping until no visible sign of particles exists.

10. Obtain the tare weight of the filter paper (+0.0001 gm) and record (weight #4).

11. The calculations are:

weight #1 - weight #2 = net media weight

weight #3 - weight #4 = net contaminant weight

$$\frac{\text{net weight of contaminant}}{\text{net weight of media}} \times 100 = \text{percent of contamination}$$

4.3.7.3 Procedures for Determining Residual Stresses in Metallic Substrates. To assess the implied residual stress due to PMB use the following test.

1. Shear a minimum of ten Almen strips (0.75" X 3.00") designed, per MIL-S-13165, from 0.032-inch 2024-T3 bare aluminum sheet (Fed Spec QQ-A-250/4). Orient the Almen strip in the rolling direction of the sheet.

2. Subject the base aluminum strip to 30 seconds of continuous exposure from the plastic media blast at a 30 psi nozzle pressure, 30-degree angle of attack, and 18-inche stand-off using a 3/8-inch nozzle diameter and a minimum mass flow of 30 lbs/hr.

3. Measure the average of ten Almen arc heights to the nearest 0.1 mil with a dial indicator. The average value should not exceed the arc height for the different mesh sizes shown below. Mesh sizes, the varying size of plastic abrasive, are defined in MIL-P-85891.

MAXIMUM ARC HEIGHT LIMITS

U.S. STANDARD SCREEN SIZE	MAXIMUM ARC HEIGHT (MILS)
12/16	< 15.0
16/20	< 12.0
20-30	< 10.0
30-40	< 7.0

PARTICLE SIZE DISTRIBUTION

4.3.7.4 Procedure for Determining Minimum Stripping Rate of Plastic Media.

1. Prepare test panels of 2024-T3 bare aluminum (6" X 12"):

- Alkaline clean using detergent material conforming to MIL-C-38334.
- Deoxidize the panels using MIL-C-38334 material.

- Within four hours, chemically conversion treat the test panels using MIL-C-81706 materials applied IAW MIL-C-5541.
- Apply epoxy primer (MIL-P-23377 type II) to the chemically converted surface of the panels to a dry film thickness of 0.0006-0.0009 inch and dry for at least 30 minutes.
- Apply polyurethane topcoat (MIL-C-83286, FED STD 595, Color No. 36495) to the primed surface to a dry film thickness of 0.0017 to 0.0023 inch.
- Cure the painted panels for seven days in an air-conditioned laboratory environment maintained at 72 degrees F and 50% relative humidity or conduct an accelerated cure in an oven maintained at 210 +/- 25 degrees F for 96 hours.
- Monitor the primer and topcoat thickness of each test panel to make sure the paint thickness is within tolerance. Take measurements directly on the substrate surfaces at six locations on the panel IAW ASTM standards, B499 and B244, using a coating thickness gap to a resolution of 0.01 mil.

2. To determine stripping rates blast at least five painted panels using a 3/8-inch diameter nozzle at 30 psi, an 18-inch stand-off, and 30-degrees angle of attack with a media mass flow rate of 300 lbs/hr. Record the paint stripping times to the nearest 0.1 second and average the results for the five panels expressed in square feet per minute. Minimum strip rates by media mesh sizes are indicated below.

MINIMUM PAINT STRIPPING RATES

Minimum Mean U.S. Standard Mesh size	Strip Rate (ft sq/min)
12/16	0.35
16/20	0.30
20/30	0.20
30/40	0.10

4.3.7.5 Specification for Determining Plastic Particle Breakdown. Minimum breakdown rates for PM are needed for both economic reasons and to minimize dust in the work environment. To determine the breakdown rates, the following procedure is followed.

1. Blast a ten pound U.S. Standard 20/30 mesh sample (conforming to particle size distribution in MIL-P-83891) against an aluminum plate (15" X 15" X 0.25", conforming to QQ-A-250/12, T6 temper) until all of the charge PM is consumed.

2. Blast in a pressure pot blast cabinet with the media reclamation system turned off or disabled. Blasting parameters are a 1/4-inch nozzle, 60 psi pressure, 80-degrees angle of attack, and 10-inch stand-off with a media minimum mass flow rate of 60 lbs/hr.

3. After each blast cycle, collect the media and recharge the system. Repeat the procedure until five cycles are completed. Measure the particle size distribution of the collected abrasive after five blast cycles IAW MIL-P-85891. Particle size distribution of the blasting abrasive shall exceed the following:

PARTICLE SIZE DISTRIBUTION AFTER 5 BLAST CYCLES
(Starting material is 20/30 mesh abrasive)

U.S. Standard Mesh Size	Minimum Percent Retained
40	40
60	70

4.3.7.6 Preparation (cleaning and masking) of aircraft for PMB.

1. Remove all cowlings, doors, power train components (engines, transmissions, gearboxes, etc.), avionic components, fuel and oil lines, and fuel cells.

2. Clean aircraft surfaces/components per TM 55-1500-344-23.

3. Mask aircraft door openings using 3M tape No. 510 or equivalent, seal doors using 3M gray duct tape No. 393 or equivalent and .005-inch visqueen plastic or equivalent. Reinstall the doors.

4. Mask aircraft cowling openings with the same tapes and techniques cited above and reinstall the cowlings.

5. Mask all transparent plastic and glass surfaces. Fabricate form-fitting metal or wood shields for canopies and blisters. For windows, use 3M No. 510 or YR-5OO material and cut to size. A scrap window or rubber sheeting also may be used.

6. Mask or plug all remaining holes and gaps on the aircraft/components to prevent intrusion of PM. Also mask bearings, drive shafts, scuppers (drains), and all moving surfaces, actuators, and linkages. Mask all cadmium plates or conversion coated/anodized hardware that will not be replaced in subsequent operations.

4.3.7.7 Procedures for Depainting and Stripping Aircraft Surfaces.

1. Position the cleaned and masked aircraft/components at the PMB site.

2. Dress PMB operators in the protective gear IAW with specifications.

3. Using a hypodermic needle gauge, verify that the indicated pressure readings, at the nozzle (taken at a 45-degree angle away from the flow of the media), meet the requirements of Table I, Column c.

4. Ground all equipment and aircraft components per requirements.

5. Remove the organic coatings from the aircraft surface using PM Type V, Grade A using the operating parameters specified in table I. Note: Maintain a minimum stripping rate of 0.50 sq ft/min.

6. The certified operator(s) should keep the nozzle moving at all times and maintain the stand-off distances, pressures, and impingement angles (angle of attack) specified in Table I. This technique will enable the operator to remove one layer of organic coating at a time from the aircraft surfaces and will decrease the dwell time spent in any one area. Dwell time should not exceed Table I specifications. Note: Since blasting operations are physically tiring, operators should be relieved at least every three hours. These rotations are necessary to maintain efficiency and prevent fatigued operators from damaging aircraft skins or components.

4.3.7.8 Clean up After PMB and Preparation for Repainting.

1. When the necessary organic coatings are removed by PMB, thoroughly vacuum all surfaces of the aircraft, equipment, or component with a heavy-duty, pneumatic type wet/dry vacuum cleaner to remove all organic coatings, dust, and media residue. This in prepares the surfaces for satisfactory paint adhesion.

2. Remove all masking materials.

3. Inspect previously masked interior areas and crevices for dust or media particle presence and vacuum as required.

4. To remove Type V, PM residue from the aircraft surface in preparation for repainting, clean the surface IAW TM 55-1500-344-23 and prepare for repainting per TM 55-1500-345-23.

4.3.7.9 Quality Assurance Requirements. Note the use of PMB on the processed aircraft structural parts in the aircraft logbook. Quality Assurance shall:

1. monitor the PMB process and examine the end items making sure the requirements of the specification are met,

2. verify that only an approved and properly maintained blast facility is used IAW the specifications, and

3. verify that only certified PM is used for the process IAW specifications.

4.3.8 Disposal Guidelines for Used Plastic Media. MIL-P-85891, Type V, Grade A acrylic resin is classified as a non-hazardous material, and its use, transportation, and storage are not subject to environmental restrictions. As such, its resin or dust may be recycled or disposed of in a sanitary landfill IAW federal, state, and local regulations. However, when using acrylic PM to remove aircraft coatings containing heavy metal pigments of arsenic, barium, cadmium, chromium, lead, mercury, selenium, or silver, the dust may be classified as hazardous waste. This may be determined by an EPA toxicity test. If the waste is hazardous, its disposal should be IAW EPA (federal), state, and local regulations where the PM operation takes place.

4.4 NAVAL DEPOT TECHNICAL ORDER

4.4.1 Introduction. The Navy has authorized the general use of PMB on aerospace hardware and metallic structures 0.016 inches thick or greater. Testing composites is still in progress. Naval Air Systems Command issued the Navy's PMB specification, "Plastic Media Blasting Process Specification for Metal Surfaces," 19 Jun 91. The PMB process described in the specification applies to all aluminum airframes and airframe components, 0.016 inches thick, or greater, and steel and titanium. The specification does not apply to composites. The process is intended, primarily, to replace chemical coatings removal. PMB can supplement chemical coatings removal by removing residual coatings, coatings unaffected by chemical removers, or selectively removing coatings. While it can remove some superficial corrosion products, the PMB process is not authorized or adequate as a complete corrosion removal technique. Remove all corrosion according to local process specifications or NA-01-1A-509 as appropriate.

4.4.2 Special Equipment. Blast cleaning cabinets, booths, and portable equipment shall be specifically designed for use with PM. The blast parameters described in the specification are highly equipment dependent. The equipment must work well to achieve consistent process control and efficiency. All equipment systems used for airframes, except for glove cabinets, shall be capable and configured to meet the requirements below.

1. A reclamation system shall remove contamination, as described in the quality control section, to a level not to exceed 0.020% by weight. This is optional for component booths and cabinets if the contamination level is monitored and media changed as required.

2. The reclamation system shall be equipped with vibratory screens capable of reclassifying the recycled media to any size distribution, defined in MIL-P-85891, by changing the installed screens.

3. The maximum media feed rate shall be at least 800 lbs/hr, controllable and reproducible to +/- 10% between 450 to 550 lbs/hr. The media shall feed smoothly at low nozzle pressures, down to 15 psi, without restricting the air path with a choke valve or other device. A design using a master-slave regulator configuration with a range of 15 to 90 psi and a master-slave differential capability of at least 0 - 10 psi is acceptable, and preferred, provided the regulators are sized to be unrestricted to maximum CFM design capability of the blast air path and the design is non-fouling.

4. The blast nozzle size shall be 1/2 inch with a blast hose inter-diameter (ID) of 1-1/8 to 1-1/4 inches except that a flexible hose extension, with 7/8-inch ID, may be used for tight radiuses.

5. The media feed vessel shall have direct pressure. The media mixing shall occur in the blast air path before the blast hose.

6. Equip the unit with a magnetic particle separator. Except for glove cabinets, the removal efficiency shall be 90% for an input contamination level of .15% by weight of magnetic particles.

4.4.3 Special Materials. The materials below are recommended for masking. Use other materials as needed for local requirements.

1. MIL-P-85891 (AS) PM, for removing Type V organic coatings.

- Use a sieve range of 20-30 or 20-40 for aluminum or magnesium sheet surfaces.
- One gram of media shall fully dissolve in 100 mls of methylene chloride in 8 hours with continuous stirring. Reject particles that swell.
- The media shall contain no toxic metal compounds with characteristic limits defined by 40 CFR.261, even if the limits are below the threshold.
- Grade B media shall have an ash content equal to or less than 0.5 % by weight.

2. Protex 8216-2L, Mask-off Co., Monrovia, CA 91016 or equivalent.

- Polyester film with pressure sensitive acrylic adhesive liner.
- Adhesive will not crease or transfer to MIL-P-25690 plastic.
- Thickness: 2.0 Mil +/- 5%.
- Elongation: 50% +/- 5%.
- Adhesion to steel, minimum 1 to 3 oz/in.

3. 3M YR-500 blast masking tape or equivalent.

- Adhesive film with liner.
- Abrasion resistant elastomer.
- Elongation: 120% +/- 5%.
- Thickness: 1.3 mm +/- 1 oz/in.
- Adhesion to liner: 1 oz/in width.
- Adhesion to steel: 26 oz/in width +/- 1 oz/in.

4. Prestite putty sealant, NSN 8030-01-183-1721.

5. MIL-T-23397 aluminum foil tape.

6. L-P-378 polyethylene film.

7. MIL-B-131 barrier film.

8. Plastic and rubber plugs and caps, sizes and shapes as required.

9. Quality control materials.

- 3M electronic liquid fluorinert FC-70 (3M Company, Industrial Chemical Products Division) or a suitable fluid with a specific gravity between 1.8 and 1.94, 1.94 being the preferred value.
- Analytical balance (capable of 0.0005 gram precision).
- Oven (capable of 105 degrees C).
- Separatory funnel (500 milliliters).
- Sieve (3-inch diameter, 200 mesh).
- Filter paper (Whatman No. 4 or equivalent).

4.4.4 In-shop Maintenance. Establish a shop Standing Operating Procedure (SOP) to provide routine maintenance instructions. Instructions should include cleaning screens, flooding, and magnetic particle separators and checking dust bags and filters for clogging. Follow the manufacturer's instructions for operator maintenance of blast equipment. Clean facilities weekly to remove accumulated residue. All operators shall complete training for maintenance of the blast equipment.

4.4.5 General Instructions.

4.4.5.1 Cleaning. To avoid contaminating the media, remove lubricant, grease, carbon, and soils IAW NA 01-1A-509, program publications and local specifications using aircraft cleaning compounds and solvents, such as MIL-C-85570, MIL-T-81772, TT-I-735, or other cleaning material and techniques, as required and allowed. Clean surfaces to be masked sufficiently to permit adhesion of the masking materials.

4.4.5.2 Masking.

4.4.5.2.1 General. This includes all preventative measures such as covering, capping, taping, sealing, plugging, or attaching preformed covers. The purpose of masking is to prevent surface and foreign object damage and system failure. Use materials listed in the special materials paragraph above. The recommended masking technique for airframes, to prevent media intrusion through narrow openings, is to apply prestite putty to the opening, then taping over the putty with the blasting tape.

4.4.5.2.2 Airframes and airframe subassemblies. Mask components that are sensitive to blast damage and locations where media may intrude into the airframe, including all nonmetallic components not intended for blast cleaning and all openings, joints, and interfaces. Examples are canopy, fiberglass and composite surfaces, lenses, openings, slots, crevices, louvers, scoops, probes, intakes, tubing, and hydraulic lines. Seal the borders of all avionic, electrical, and mechanical compartment access covers, even when fastened to the airframe. The only exception is flush seam joints on the exterior skin.

4.4.5.2.3 Components. Mask oil passages, tubing and blind/dead end fastener holes or other inaccessible openings. Also, mask weight and balance sensitive components, such as control surfaces and rotor blades. Cover close tolerance interfaces and grooves that may trap media. Blast components before disassembly, when possible, to reduce the amount of masking and the potential for media intrusion.

4.4.5.3 Blast Operations.

4.4.5.3.1 Equipment. Equipment shall always be adjusted to optimum air flow/media mixture. The maximum nozzle pressure is 30 psi. This will not always be acceptable on inadequately supported surfaces. Increase the pressure from initial settings while observing for visual damage cues. Examine the work frequently (typically every 60 seconds) during prototyping and make pressure and media feed adjustments, as necessary. Adjust media feed after each pressure change.

4.4.5.3.2 Media feed adjustment. An observer will be required for calibrating the feed valve setting and to record removal rate times. This procedure is not required with electronically controlled preprogrammed adjustment.

1. Attain the initial adjustment by setting the media flow control valve fully open or until surging is observed.

2. Follow the adjustment procedure while removing small sections of coating (1-2 sq ft) and recording the removal times.

3. Reduce the media feed valve opening by increments. Remove the selected areas of coating and record the removal effect and time. Calculate the removal rate per standard unit area. Continue until the removal rate begins to decrease. As the media feed valve opening is incrementally closed, the removal rate should be observed to increase to a maximum, and then decrease as media feed becomes excessively lean. The optimum feed rate is at a point of maximum removal rate. Reset the media feed valve to a position just slightly rich.

4. If the removal rate decreases continually from the maximum feed valve setting, then the optimum feed rate is above the maximum valve capacity and the equipment does not meet performance requirements.

5. The differential pressure or choke valve should be fully open during operation of the blast units.

6. Constantly observe the blast stream for feed obstruction. Do not use equipment that exhibits surging feed or lean feed conditions.

4.4.5.3.3 Technique. The following are guidelines for damage prevention.

1. Use the minimum blast pressure and maximum nozzle stand-off distance, which will effectively accomplish the work. The maximum allowable nozzle pressure is 30 psi and the standard nozzle stand-off distance is 24 inches.

2. Dwell time begins once bare metal is exposed. Avoid excessive blast pattern overlap. Except when blasting to primer only, avoid leaving residual coating specks that will require reblasting, since the dwell time, and the residual stress, are cumulative.

3. Use proper ground support equipment to attain an optimum operator blast position. This provides the most potential for manipulating and maintaining an effective blast angle and distance.

4. Do the most difficult areas first, before operator fatigue becomes a factor in process control.

5. Blast the fastener patterns first, then move outward. This reduces dwell and residual stress on unsupported areas.

6. Remove layered paint using a fanning motion instead of blasting to metal on a single pass.

4.4.5.3.4 Loose Masking. In the event masking should become dislodged, the masking shall be immediately replaced or the surrounding area bypassed. If effective masking cannot be innovated, or if media enters a normally inaccessible area, this shall be documented for corrective action.

4.4.5.4 Damage Recognition. Observe for visual evidence of substrate damage during blasting. Determine the cause of the damage and take corrective action.

1. Metal flow is visually evident. The indication will be a polished appearance and/or the removal of the surface treatment. If this has happened, etch the components requiring subsequent fluorescent penetrant inspection before inspection. An additional inspection method may be authorized by local process specifications or NA 01-1A-16 may be used.

2. Peening alclad or damage to conversion treatment, either chromic acid anodize (MIL-A-8625, type I) or chromic conversion treatment (MIL-C-81706) on alclad, may be noticeable and is allowable.

3. Distorting sheet metal is not allowable.

4. Paint residue is allowable, extending up to 2 mm from raised fasteners, provided paint passes a dry tape test.

5. Blasting interior surfaces on airframes increased the potential for distortion.

4.4.5.5 Clean Up. Immediately following coating removal, clean all surfaces and treat bare metal surfaces IAW NA 01-1A-509, systems manuals, or local process specifications.

1. Blow off excess media using compressed air and vacuum or otherwise remove entrapped media.

2. Visually inspect all blind/dead end fastener holes and oil passages for trapped media.

3. Flush all oil passages with P-D-680, Type II fluid and inspect as required.

4. Type V, PM may leave an organic film residue. This must be removed for proper conversion treatment and coating adhesion. Cleaning procedures shall include a step using a solvent effective for removing acrylic plastic residue.

5. Clean and conversion treat all bare metal surfaces using procedures in NA 01-1A-509, preceded by a solvent wipe using MIL-T-81772 or appropriate local procedures.

6. Removal of well-bonded seam sealant is not required, except for cause only, as required for corrosion removal, NDI procedures, disassembly or assembly. This does not apply to sealant used for masking.

4.4.5.6 LOG Book Entry. Maintain log books for the PMB process. Make dated entries for process times as follows: "Plastic media used for external paint removal." Enter the location, station, and waterline number, if removal was partial.

4.4.5.7 Safety.

1. At least two employees shall be present in any blast area where manned blast booth or open area blasting is in operation.

2. Blasters shall wear respiratory protection prescribed by the cognizant Occupational Safety and Health Office and the Industrial Hygiene Activity.

3. Post the shop's SOP for respiratory protection at the blasting area.

4. Manned blasting equipment has been designed to operate with up to 95 degrees F wet bulb temperature. If the work area gets too hot, give the employees the necessary work-rest cycle to prevent heat stress.

4.4.5.8 Quality Control. The heavy particle contamination limit is 0.020% by weight. Heavy particles are mineral like abrasive, metal fragments, and corrosion products. Monitor all aeronautical PMB operations for heavy particle contamination using standard statistical process control techniques as determined by the Material Engineering Division or as defined in a contractor's statement of work. Profile equipment, such as glove cabinets, which are used for components and are not configured with a heavy particle separator, for a rate of contamination build-up. Change the media on a regular schedule to prevent it from exceeding the 0.020% contamination limit. Recycle this media into equipment configured with a heavy particle separator. Do not process ground support equipment in the same blast systems as aeronautical components. Remove corrosion from aeronautical steel parts exhibiting rust scale before processing with plastic media or dedicate a unit to this workload. Measure heavy particle contamination by; flotation using the following procedure or equivalent procedure developed by the Material Engineering Division.

1. Add 400 ml of 3M fluorinert FC-70 (density=1.94) to a 500 ml separatory funnel.

2. Add approximately 100 g (actual weight = S) of PM to the separatory funnel.

3. Vibrate the funnel from side to side while in an upright position for 1-2 minutes.

4. Allow the funnel to stand upright and undisturbed for 5 minutes after vibrating it.

5. Drain the settled material from the funnel into a clean 200 mesh sieve screen. Reuse the fluorinert FC-70 by filtering it through Whatman No. 4 filter paper.

6. Dry the sieve screen to a constant weight in a 105 C oven.

7. Weigh the retained particles (weight = R) and calculate the contamination level as follows:

$$\text{PERCENT} = \frac{100 \times R}{S}$$

4.4.5.9 Training. Properly train and certify all operators to perform the PMB process IAW the most stringent interpretation of local training and quality instructions. PMB requires extensive operator training and process controls to avoid damage to substrate materials. Incorporate the following summary of training requirements in the local process specification and forwarded it to the NADEP code responsible for training and curriculum development.

1. A 3-5 day formal training program to consist of lectures and demonstrations.

2. Hands-on training covering blasting and paint removal from scrap parts and ample test material.

3. Are-certification program for operators not involved in PMB for 6 months or more.

4. Formal training shall include the following:

- Theory and practice of plastic PMB.
- Equipment design and characteristics.
- Recycling and cleaning equipment.
- An understanding of blast parameters and control/monitoring thereof.
- Description and explanation of the types of coatings and substrates to be blasted.
- Blasting techniques and means of masking and protecting areas from unwanted blasting and media intrusion.
- An understanding of safety requirements and personal protective equipment.

SECTION V - COSTS

5.1 Introduction. Environmental pressure to move away from chemical strippers that generate large amounts of hazardous waste is the impetus for the development of alternative paint stripping methods. However, to find an environmentally acceptable alternative that meets engineering specifications, cost is always a major, if not the foremost, concern. As alternative methods, new media, and process equipment are engineered and developed, they must be evaluated in a total system that accounts for installation and purchase cost, maintenance needs, cost of consumable masking material and blast media, labor costs, suitability of the process, and disposal costs of the residual materials.

5.2 IMPLEMENTATION COST

5.2.1 General. Implementation cost for a stripping process or facility may not be the primary driver for adopting a particular paint stripping method since funding for procurement is based on long-term payback of the investment. The actual cost to operate a system cannot be known until a reasonable level of experience is obtained and operational data is developed. The data will include bulk strip rates, medis costs, media breakdown rates, operator skill requirements, equipment maintenance, equipment down time, and labor-hour requirements for prestripping, touch up, and post stripping operations. Once they know actual production cost performance figures, future planners may use the data for decisions to implement similar processes based on the specific merits of the documented process. The most common error in judgement made by process and facility planners is "over kill." There is a tendency to procure equipment with capabilities and capacity in excess of the requirement to make sure all contingencies are covered.

5.2.2 Investment Costs.

5.2.2.1 The initial cost for a PMB system cannot be expressed as a fixed figure for use by activities desiring to purchase a turnkey operation. Appendix III provides a list of organizations within the DOD depot maintenance community that have implemented PMB operations. It is highly recommended that for specific tasks, organizations with similar functions be contacted. Variations in design must consider equipment, location, supporting utilities, safety, and environmental interaction. The size of an operation or blast facility may be large enough to house C-5 Galaxy cargo aircraft or a small enough for simple components. In either case, the methods used to assess PMB performance requirements and to match those requirements with facility size and performance characteristics are essentially the same. The Navy has developed a guide for designing and implementing large and small blast booths: Naval Energy and Environmental Support Activity (NEESA) 19-005. The information provided in this document is pertinent for general use and reflects Navy practices for equipment and material standardization.

5.2.2.2 As the complexity and size of the process equipment increase, so do the installation costs. Projecting the worst case scenario may result in procuring equipment that is unnecessarily complicated or expensive. For example, to procure high-density contamination separation equipment, the RFP/RFQ will specify the process requirements in terms of pounds to be processed per hour. Yet, to date, no one has provided information in an RFP/RFQ on what a representative contamination level might be at the time of processing. The cost will be much lower for equipment that will process 1,000 pounds an hour than for equipment required to process 10,000 pounds, with all other requirements being equal. Likewise, equipment that must process contaminated media to a level of 300 ppm, will be much less complicated and costly than equipment required to remove high-density contamination at a level of 1,000 ppm.

5.2.2.3 The Puget Sound Naval Shipyard (PSNSY) investment cost for a 10' X 10' X 15' blast enclosure and associated equipment was $150,000 in Apr 1990. The system included two blast pots with a 6-cubic-ft capacity and media classification equipment (cyclone separator, magnetic particle separator, and vibratory deck). Recover media by vacuuming the media through hoses connected to vacuum ports in the side of the booth. The system was installed to accommodate small parts that normally would be stripped in a 2,000 gallon methylene chloride paint strip tank.

5.2.2.4 San Antonio ALC, Kelly AFB, TX, installed a PMB facility in Jul 1992 designed to strip coatings from B-52 and C-5 aircraft. Payback on this facility is expected by 1995. At the May 93 DOD/Industry Advanced Coatings Removal Conference, SA-ALC reported stripping seven C-5, one B-52, three F-16, and one T-37 aircraft in the facility. The ALC has scheduled one C-5 aircraft for stripping every week for the next two years. Stripping costs are:

Electrical	$24,000
Labor	102,000
Media	10,000
Hazardous waste	5,000
Consumable	10,000
Total	$151,000 Cost per C-5 aircraft

The savings over chemical stripping with type V media per C-5 aircraft is 2,000 man-hours. The process will save $4,800,000 a year and eliminate 72,000 gallons a year of methylene chloride stripper. The only areas not PMB processed are fiberglass, which means that 90% of the C-5 is dry stripped. The fiberglass areas are scuffed and painted.

5.2.3 Costs/Payback.

5.2.3.1 The factors that should be considered in evaluating comparative costs and the payback period for conversion to PMB are illustrated by data gathered at Hill AFB in 1987. The data was gathered during the stripping of F-4 aircraft using chemical stripping and PMB. The comparison shows that using PMB instead of chemical stripping saves $12,582 per aircraft. For a capital investment of $1,400,000 and a workload of 150 aircraft per year, the payback period for converting to PMB stripping is approximately nine months for this application. The evaluation factors and costs (per F-4 aircraft) are:

1. For chemical stripping:

   - Labor = 346 hours at $45.00/hr ($16,380)
   - Chemical use = 468 gallons at $11.40/gal ($5,335)
   - Water treatment/disposal = 200,000 gallons at $8.24/1000 gal ($1,648)
   - Heating, ventilating, and air conditioning (HVAC) = $1,347
   - Maintenance = $667 (note that chemical strippers can corrode concrete)
   - Electricity = $333 for ventilation fans

- Hazardous waste = 1024 pounds of paint and solvent sludge at a disposal cost of $200/ton ($102)
- Water use = 200,000 gallons at $0.43/1000 gal ($86)

TOTAL = $25,898/aircraft

2. For PMB stripping:

- Labor = 183 hours at $45.00/hr ($8,235)
- Plastic media = 1,500 pounds at $1.76/lb (2,640)
- Maintenance = $1,333 for PMB facilities and mechanical equipment
- Non-PMB costs = $667 to strip components that cannot be done using PMB
- Hazardous waste = 1,700 pounds at $260/ton ($221)
- Electricity = $173 for ventilation fans and air compressors
- HVAC = $47

TOTAL = $13,316/aircraft

5.2.3.2 Estimating the cost of a PMB system, as a replacement alternative, for stripping heavy iron is more difficult. Most of the cost data have been developed for stripping large uniform surfaces rather than the variety of parts and sizes that must be handled at PSNSY. PSNSY, who has concluded that PMB effectively removes common shipyard coatings, has been unable to fully use PMB or adequately evaluate it against other paint removal processes. During the two and a half years that their PMB booth operated, it was used a total of 722 hours. Of the 722 hours, the actual blast time (nozzle time) was 247 hours. As a result the following operating cost data were collected from Apr 90 - Oct 91:

1. Factors:

- Total amount of media used = 13,000 lbs
- Total nozzle time (from hourmeter) = 161.9 hrs
- Total booth operating time (from hourmeter) = 457.4 hrs
- Booth operating time per 8-hour shift = 6 hrs (75% of shift)
- Sandblaster labor rate = $37.23 per hr
- Media cost (Type II, Grade B) = $1.50 per lb
- Hazardous waste disposal cost = $4.09 per lb*

* This cost is an accounting figure used at PSNSY that includes all expenses (direct and indirect) related to hazardous waste management and disposal on a per lb basis.

2. Material cost per nozzle hour: $\frac{13{,}000 \text{ lbs}}{161.9 \text{ hrs}} \times \$1.50/\text{lb} = \$120.45/\text{hr}$

3. Manpower cost per nozzle hour:

percent of nozzle time: $\frac{75\% \times 161.9 \text{ hrs}}{457.4 \text{ hrs}} = 0.266$

$$\frac{\$37.23/\text{hr}}{0.266} = \$139.96/\text{hr}$$

4. Disposal cost per nozzle hour: $\frac{\$4.09/\text{lb} \times 13{,}000 \text{ lbs}}{161.9 \text{ hrs}} = \$328.43/\text{hr}$

5. Maintenance cost per nozzle hour:

Maintenance costs were documented Oct 91 - Aug 92. 32 man-hours and $30 in materials were expended. During the same time period, 84.9 hrs of nozzle time was logged (actual blasting).

$$\frac{32 \text{ hrs}}{84.9 \text{ hrs}} \times \$21.83/\text{hr} = \$8.23/\text{hr}$$

6. Total cost per nozzle hour: $120.45 + $139.96 + $328.43 + $8.23 = $597.07/hr

5.3 PLASTIC MEDIA COSTS

5.3.1 General. Total cost involves not only the price of the media but the consumption rate, cleaning rate, labor, and disposal. Disposal costs for used media are affected by what is being stripped (paint composition). Consumption rate (how many times the media can be reused before being discarded) obviously affects total media usage cost.

5.3.2 A cost comparison for labor and media is shown below for the various media and stripping parameters necessary to achieve various Almen arc heights. This information is adopted from the proceedings of the 1990 DOD/Industry Advanced Coatings Removal Conference, "Physical Properties and Performance of a New Non-Plastic Media for Paint Removal," by Rubin Lenz, Ogilvie Mills Ltd.

1. For arc height 0.004 inch to 0.010 inch:

Media	Melamine	Melamine	Acrylic	Urea
(mesh)	(20/40)	(40/60)	(40/60)	(20/40)
Pressure (psi)	15	25	70	25
Flow rate (lbs/hr)	240	374	521	314
Cleaning rate(sq ft/hr)	8.4	38	72	62
Labor cost @ $15/hr ($/sq ft)	1.79	1.41	0.21	0.24
Cost of media ($/sq ft)	1.30	1.02	1.25	0.94

2. For arc height greater than 0.010 inch: (not for aircraft paint removal)

Media	Melamine	Melamine	Acrylic	Urea
(mesh)	(20/40)	(40/60)	(40/60)	(20/40)
Pressure (psi)	40	25	40	25
Flow rate (lbs/hr)	362	298	412	235
Cleaning rate (sq ft/hr)	111	73	40	98
Labor cost @ $15/hr ($/sq ft)	0.19	0.16	0.38	0.20
Cost of media ($/sq ft)	0.88	0.40	0.80	0.43

5.3.3 Consumption rate has a direct bearing on total usage costs. Media particles smaller than 60 mesh generally have little paint stripping value. This is related to the low amount of energy particles of this size can deliver to the painted surface. Below are test results on consumption generally following MIL-P-85891.

A is the percent of virgin media particles greater than 60 mesh.
B is the percent of remaining particles greater than 60 mesh after 5 blast cycles.
The total consumption percentage is the difference between the two (A% minus B%).

Medium	percent A	percent B	percent total consumption after 5 blast cycles A - B
Type I	99.91	60.15	39.76
Type II	99.82	50.15	49.67
Type III	99.71	31.03	68.68
Type V_l	99.74	87.97	11.77
Type V_x	99.64	80.45	19.19

5.4 DISPOSAL COSTS

5.4.1 Introduction. The cost for waste disposal is a growing concern. Projecting that environmental costs will continue to grow, process planners must assign a high priority to those considerations related to waste stream treatment methods. The PMB waste stream consists of an inert nonhazardous plastic dust, trash accumulated in the system, and a small amount of hazardous heavy metal found in the paint chips. While separation techniques can remove some hazardous paint chips from the plastic dust, environmental managers do not want to risk a government liability for future land fill contamination accusations. If the possibility exists that the government put known hazardous waste materials in a landfill, then the government may be required to assume responsibility for cleaning up the entire landfill. Therefore, many bases treat their plastic waste as hazardous waste, regardless of whether the sample test for toxic content indicates acceptable levels. Disposal options include solidifying the plastic dust and dumping it in appropriate landfills, burning it in approved hazardous material incinerator furnaces, or using it as a fuel additive in authorized cement kilns. The media may be treated to remove or detoxify the hazardous paint chips by acid leaching, separation, or biologic action. Another alternative is to pay the media supplier to take the waste media back for recycling.

5.4.2 Landfill Disposal. The EPA land ban program that prohibits dumping 35 or more hazardous leachable chemicals in landfills effectively has changed the outlook on waste disposal. Plastic media waste must pass the toxicity test to be placed in any landfill. The Class A hazardous landfill permit apparently is eliminated, making all waste material conform to the leaching test specification before dumping at any landfill. This means PMB material will have to be charred, detoxified by leaching out the hazardous chemicals or using biologic agents, or encapsulated enough to pass the leaching test. Presently, the cheapest form of inerting the material is to encapsulate the media in cement and then dumping it in a landfill.

5.4.3 Incineration. Burning PM waste by-products is the most expensive method of disposal available. One drum filled with 53 gallons of hazardous waste costs from $400 to $1200 to incinerate through hazardous waste contracts. The PM is transported to an approved incinerator and placed into the furnace at 2200 F. The plastic is completely incinerated and the heavy metals are transformed into vapors, oxides, and ash. The resulting ash waste is tested for leachability then disposed of in an appropriate landfill.

5.4.4 Cement kilns. Cement kilns provide a safe, effective, and economical method not only to dispose of the waste, but also to use the energy stored in the spent plastic media to produce a commercially viable product, portland cement. The plastic media, an energy bearing material, is used to supplement coal as the energy source for the kiln and, thereby, provides an effective means of resource recovery. The cost for cement kiln destruction of PM currently is 50 to 90 cents per pound of waste, depending on its location and volume. Efforts with DLA to list large hazardous waste streams as single items for disposal contract bids will permit greater use of the cement kiln process at organizational and depot maintenance facilities using PMB. PMB reduces virtually 100 percent of the spent PM presently going to landfills. Reusing waste materials to produce a commercially sold product reduces the dwindling landfill capacity. The cement plant benefits from reduced coal consumption and emissions when seeding the furnace with alternative fuels. The liability of hazardous waste generators will be reduced, since the material is converted to ash and encapsulated in cement as a benign filler. Environmental concerns for this method of waste disposal include kiln stack emissions, air pollution, and product quality and liability.

5.4.5 Detoxification of waste. Waste plastic media can be dumped in landfills for little cost, if the material can be treated to inert the leachable contaminating materials. Charring the waste and chemical leaching of the heavy metal contaminates have been tried with some success. Separating heavy particles from the media is easily done by density separation of paint chips. Liquid separation, However, is an option that results in a multiple waste stream. Some organizations currently char waste media before putting it in a landfill. Charring, an acceptable method with reasonable costs, is similar to encapsulation, but has better long-term benefits. Possible future leachability of encapsulated toxins is a continuing question but, by charring the PM waste, the material is transformed into a non-leachable form.

5.4.6 Biodegradation. Biotechnology has been used successfully in laboratories to separate paint chips from PM and to digest acrylic blast media for a reduction in volume. The technology is projected to be significantly cheaper than current disposal alternatives. Continuous or batch waste media processing is projected to cost 5 to 10 cents per pound. Current efforts to demonstrate the practical application of this technology have resulted in continuous process methods for batches in the 10-gallon-volume range. The size of the process must be increased a hundred fold to treat industrial volumes of waste.

5.4.7 Recycling plastic media. Thermoplastic blasting media, such as Type V acrylic, can be recycled by heating the media to a liquid or plastic state and reforming it. The objective is to mix and encapsulate the waste material into a hardened form that exhibits the non-leachable, non-toxic characteristics required for reuse in the public sector or to use the waste material as a bulk filler in construction materials. Implementing a recycling program is difficult because contractors supplying the recycling service require that the media be purchased from them, making the process a sole source procurement. Organizations that have evaluated the Type V media recycling option have not incorporated an active program because of the increase in media purchase price.

APPENDIX I

APPENDIX II

LIST OF STUDIES AND REPORTS ON PLASTIC MEDIA BLASTING.

1. Amro, Joe P. and Talia, Jorge E., "Mechanical Paint Removal Techniques for Aircraft Structures," NIAR Report 90-12, National Institute for Aviation Research, Wichita State University, Wichita KS, 67206-1595, May 90.

2. Bergman, Dave D., "Laboratory Evaluation of Corrosion Susceptibility of Anodized Aluminum 7075-T6, Paint Stripped with Plastic Bead Media," Report No. 87-AF-079, Air Force Corrosion and Materials Engineering Branch, Warner-Robins Air Logistics Center,
Robins AFB GA.

3. Butkus, Capt Lawrence M.; Meuer, Capt Gary D.; and Behme, Authur K.; "An Evaluation of the Effects of Hand Sanding and Plastic Media Blasting Paint Removal on Graphite/Epoxy Composite Materials," WL-TR-91-4025, Materials Directorate, Wright Laboratory, Air Force Systems Command, Wright-Patterson AFB OH, Mar 90.

4. Childers, Sidney; Watson David C.; Stumpff, Patrica; and Tirpak, Jon; "Evaluation of the Effects of the Plastic Media Paint Removal Process on Properties of Aircraft Structural Materials," AFWAL-TR-85-4138, Materials Laboratory, AFWAL, AFSC, WPAFB OH, Dec 85.

5. Cundiff, C. and Deel, O., "Plastic Media Evaluation - An Efficiency Study for a Thin, Damage Sensitive Substrate," for E.I. Dupont Nemours and Company, Inc., Battelle Columbus Laboratories, Columbus OH, 24 Jan 90.

6. Cundiff, C. and Deel, O., "Plastic Media Evaluation - A Comparative Study," for E.I. Dupont Nemours and Company Inc., Battelle Columbus Laboratory, Columbus OH, 15 Jun 89.

7. Cundiff, C. and Deel, O., "Plastic Media Evaluation - Follow-up Study," for E.I. Dupont Nemours and Company, Inc., Battelle Columbus Laboratory, Columbus OH, 15 Jun 89.

8. Deel, Omar; Galliher, Ron; and Taylor, Gregory; "Plastic Bead Blast Materials Characterization Study," for Air Force Corrosion Program Management Office, Robins AFB GA, Jul 86.

9. Deel, Omar; Galliher, Ron; and Taylor, Gregory; "Plastic Bead Blast Materials Characterization, Follow-on Study," for Air Force Corrosion Program Management Office, Robins AFB GA, 13 Nov 87.

10. "Evaluation of Plastic Media Paint Removal Process on the Corrosion Characteristics of Aerospace Structural Materials," Air Force Corrosion Program, Air Force Logistics Command, Warner Robins Air Logistics Center, 1 Mar - 21 Jul 86.

11. Foster, Terry and Blenkinship, G. N., "Surface Preparation of Aluminum and Composite Aircraft Materials," Materials Engineering Section, Research and Development Branch, Defense Research Establishment Pacific, Dept of National Defense, Canada, Dec 86.

12. Friedman, R. F., AND Eidenoff, H.L., "Effect of Paint Removal by Plastic Bead Peening on Fatigue Life of Aluminum, Titanium, and Steel Sheet Material," EG-STAM-087-110, Grumman Corporation, 14 Jul 87.

13. Gee, Terry; Poirier, Mike; and Dodson, J.M., "Preliminary Report on Plastic Media Paint stripping from Graphite/Epoxy Surfaces," NESO North Island Materials Engineering Laboratory, Code 34000, Naval Air Rework Facility, North Island, San Diego CA, 92315, 19 Mar 84.

14. Gee, Terry,et al, "Evaluation of Plastic Media Paint Stripping (F-4S Paint Strip)," Engineering Report No. 002-85, Naval Air Rework Facility, North Island, San Diego CA, 92135, 20 Mar 85.

15. Guy, Thu-Ha; Lankarani, Hamid; and Talia, J. E., "The Effects Of Paint Removal by Natural Bead Blasting on the Surface Morphology of Composite Materials," NIAR Report 90-24, National Institute for Aviation Research, Wichita State Univ., Wichita KS, Aug 90.

16. Kenny, Andrew, "Analysis of Test Results on Bead Blasting 0.040 Inch Thick 2024-T8 Aluminum Sheet," OO-ALC/MAQCM, Ogden Air Logistics Center, Hill AFB UT,84056-5149, 26 Apr 88.

17. Kopf, Peter, and Cheney, Jay, "Paint Removal from Composites and Protective Coating Development," WL-TR-91-4025, Materials Directorate, Wright Laboratory, AFSC, WPAFB OH, Feb 91.

18. Kozal, Joseph; Thoman, Steven; and Clark, Kenneth, "The Effects of Plastic Media Blasting Paint Removal on Microstructure of Graphite/Epoxy Composite Material," NADC 88109-60, Aircraft and Crew Systems Directorate, Naval Air Development Center, Warminster PA, 18947-5000, 7 Oct 88.

19. Kozol, Joseph; Thoman, Steven; and Clark Kennith, "The Effects of PMB Paint Removal on the Mechanical Properties of Graphite/Epoxy Composite Materials," NADC 89036-60, Air Vehicle and Crew Systems Technology Dept, Code 606, Naval Air Development Center, Warminster PA 18974-5000, 3 Apr 89.

20. Mosbey, Barbara, "Evaluation of Plastic Bead Blasting on F-16 Aircraft Materials," Report N0. 16PR8908, General Dynamics, Ft Worth Division, for OO-ALC/MMARA, Hill AFB UT, 16 Oct 89.

21. Pavlik, Charles; Byers, Tom; and Christensen, J. D., "Effects of Plastic Bead Blasting on Composite Panels," Interim Report, OO-ALC/MMARA, Hill AFB UT, 16 Nov 88.

22. "Plastic Media Blasting Data Gathering Study: Final Report," NCEL CR87.006, Naval Civil Engineering Laboratory, Port Hueneme CA 93043, Dec 86.

23. Reeves, Blant N.; Sanders, Kenneth; Dr Knapp, D. O.; and McSwain, Richard, "Coating Removal Via Plastic Media Blasting: Laboratory Analysis of Physical Effects on Aircraft Materials," Materials Engineering Division, NAVAIR Engineering Support Office (NESO), Naval Air Rework Facility, Pensacola FL, 16 Jul 84.

24. Shields, S. and Klugman, H. L., "Test Report for Paint Stripping T-34C Aircraft by Plastic Media Blast," Report No. 87080601, Dynalectron Corporation, Aerospace Operations, 10 Sep 87.

25. Shields, S. "Fatigue Tests of PMB Stripped Thin Aluminum Panels," Dynacorp, 11 Jan 88, from DoD Tri Service and Industry Advanced Coatings Removal Conference Proceedings 1-3 Mar 88, pp.A-1 - A-11.

26. Sizemore and Stillwell, "Fatigue Crack Growth Evaluation of Plastic Media Blasting Paint Removal," STRU-B692B-10-C-87-299, 14 Dec 87.

27. Song, Zhenning; Yan, Jianping; Hoeppner, David, "Evaluation of the Effects of the Plastic Media Blasting Process on Fatigue Properties of Aircraft Structural Material," Dept of Mechanical and Industrial Eng., Univ. of Utah, Apr 88.

28. Stewart, R. D. and Arthur, G. L., "Prototype Removal of Aerial Camouflage Paint Finish from Underside of AV-8B, S/N 162072, Using Plastic Media Blasting," Materials Engineering Division, Laboratory Report No. 2218-86, Naval Air Rework Facility, Cherry Point NC 38533-5030, 31 Oct 86.

29. Storr, Howard J., "Effect of the Plastic Bead Blasting Paint Removal process on the Fatigue Lives of Thin Skin Materials," AFWAL-TM-88-182-FIBE, Flight Dynamics Laboratory, AFWAL, WPAFB OH 45433, May 88.

30. Svejkovsky, Don Johnson and Richter, Steve, "Plastic Media Blasting," Project Report No. 8TS197S, OC-ALC/MMEOS, Oklahoma City Air Logistics Center, Tinker AFB OK 73145, 29 Jun 89.

31. Grey, Colin A., "Removal of Paints from Defense Force Equipment Using a Plastic Media Blasting Technique," Journal of Protective Coatings and Linings, Vol 10, No.9, Sep 93.

APPENDIX III

Depots Using
PLASTIC MEDIA BLAST

Sorted by Commodity, Product, Depot

COMMODITY	PRODUCT	DEPOT
Aircraft		
	Accessories and Components	AGMC Newark
		AMARC Tucson
		Anniston AD
		Corpus Christi AD
		Letterkenny AD
		NADEP Alameda
		NADEP Cherry Point
		NADEP Jacksonville
		NADEP Norfolk
		NADEP North Island
		NADEP Pensacola
		Ogden ALC
		Oklahoma City ALC
		Sacramento ALC
		San Antonio ALC
		Tobyhanna AD
		Tooele AD
		Warner Robins ALC
	Armament	Anniston AD
		Letterkenny AD
		NADEP Alameda
		NADEP Cherry Point
		NADEP Jacksonville
		NADEP Norfolk
		NADEP North Island
		Ogden ALC
		Sacramento ALC
	Avionics	AGMC (Newark)
		AMARC Tucson
		NADEP Alameda

Aircraft

Avionics	NADEP Cherry Point NADEP Jacksonville NADEP Norfolk NADEP North Island Ogden ALC San Antonio ALC Tobyhanna AD Warner Robins ALC
Engines	AMARC Tucson Anniston AD Corpus Christi AD NADEP Alameda NADEP Cherry Point NADEP Jacksonville NADEP Norfolk NADEP North Island Ogden ALC Oklahoma City ALC Sacramento ALC San Antonio ALC Warner Robins ALC
General Purpose	AGMC Newark AMARC Tucson Anniston AD NADEP Alameda NADEP Cherry Point NADEP Jacksonville NADEP Norfolk NADEP North Island NADEP Pensacola Ogden ALC Oklahoma City ALC Sacramento ALC Tobyhanna AD Tooele AD Warner Robins ALC

COMMODITY

PRODUCT	DEPOT

Aircraft

	Metal Airframe	AMARC Tucson
		Corpus Christi AD
		NADEP Alameda
		NADEP Cherry Point
		NADEP Jacksonville
		NADEP Norfolk
		NADEP North Island
		NADEP Pensacola
		Ogden ALC
		Oklahoma City ALC
		Sacramento ALC
		San Antonio ALC
		Warner Robins ALC
	Non-metal Airframe	AMARC Tucson
		Corpus Christi AD
		NADEP Alameda
		NADEP Cherry Point
		NADEP Jacksonville
		NADEP North Island
		NADEP Pensacola
		Ogden ALC
		Sacramento ALC
		San Antonio ALC
		Warner Robins ALC
	Support Equipment	AMARC Tucson
		Anniston AD
		Corpus Christi AD
		NADEP Alameda
		NADEP Cherry Point
		NADEP Jacksonville
		NADEP Norfolk
		NADEP North Island
		NADEP Pensacola
		Ogden ALC
		Oklahoma City ALC
		Sacramento ALC
		San Antonio ALC

COMMODITY	PRODUCT	DEPOT
Aircraft		
	Support Equipment	Tobyhanna AD
		Tooele AD

	Warner Robins ALC
Automotive Equipment	
Accessories and Components	Anniston AD Letterkenny AD MCLB Albany MCLB Barstow NADEP Alameda NADEP Jacksonville NADEP North Island Ogden ALC Sacramento ALC Tooele AD
Armament	Anniston AD Charleston NSY Letterkenny AD Long Beach NSY MCLB Albany MCLB Barstow Pearl Harbor NSY Puget Sound NSY Tooele AD
Communications	Anniston AD MCLB Albany MCLB Barstow Tobyhanna AD Tooele AD
Electronics	Anniston AD MCLB Albany MCLB Barstow Tobyhanna AD Tooele AD

COMMODITY PRODUCT	DEPOT
Automotive Equipment	
Engine	Anniston AD Letterkenny AD MCLB Albany MCLB Barstow

	Ogden ALC Sacramento ALC Tooele AD
Fire Control	Anniston AD Charleston NSY Letterkenny AD Long Beach NSY MCLB Albany MCLB Barstow Pearl Harbor NSY Puget Sound NSY Tobyhanna AD
Hull & Chassis	Anniston AD Letterkenny AD MCLB Albany MCLB Barstow Ogden ALC Sacramento ALC Tooele AD
Support Equipment	Anniston AD Letterkenny AD MCLB Albany MCLB Barstow NADEP Pensacola Ogden ALC Tobyhanna AD Tooele AD

COMMODITY		
	PRODUCT	DEPOT
Combat Vehicles		
	Accessories and Components	Letterkenny AD MCLB Albany MCLB Barstow Tooele AD
	Armament	Anniston AD

	Letterkenny AD MCLB Albany MCLB Barstow Tooele AD
Communications	MCLB Albany MCLB Barstow Tobyhanna AD Letterkenny AD
Fire Control	MCLB Albany MCLB Barstow Tobyhanna AD
General Purpose	Letterkenny AD MCLB Albany MCLB Barstow Tobyhanna AD Tooele AD
Hull & Chassis	Letterkenny AD MCLB Albany MCLB Barstow Sacramento ALC Tooele AD
Power Plants	Letterkenny AD MCLB Albany MCLB Barstow Tooele AD

COMMODITY PRODUCT	DEPOT
Combat Vehicles	
Support Equipment	Letterkenny AD MCLB Albany MCLB Barstow Tobyhanna AD Tooele AD
Communications/Electronics	

Accessories and Components	Anniston AD MCLB Albany MCLB Barstow NADEP Jacksonville NADEP Norfolk NADEP North Island NADEP Pensacola Tobyhanna AD Tooele AD
Electronics	AGMC Newark Charleston NSY Mare Island NSY MCLB Albany MCLB Barstow NADEP Alameda NADEP Jacksonville NADEP Norfolk Ogden ALC Philadelphia NSY Puget Sound NSY Sacramento ALC Tobyhanna AD Tooele AD Warner Robins ALC
General Purpose	Anniston AD Charleston NSY Mare Island NSY MCLB Albany MCLB Barstow

COMMODITY PRODUCT	DEPOT
Communications/Electronics	
General Purpose	NADEP Alameda NADEP Cherry Point NADEP Norfolk NADEP Pensacola NESEC San Diego Ogden ALC Philadelphia NSY Portsmouth NSY Puget Sound NSY

	Sacramento ALC
	Tobyhanna AD
	Tooele AD
Power Plants GTE	Anniston AD
	NADEP Jacksonville
	NADEP Norfolk
	Tobyhanna AD
	Tooele AD
Power Plants Recip	Anniston AD
	MCLB Albany
	MCLB Barstow
	Tobyhanna AD
	Tooele AD
	Letterkenny AD
Radar	MCLB Albany
	MCLB Barstow
	NADEP Alameda
	NADEP Norfolk
	NADEP North Island
	Ogden ALC
	Sacramento ALC
	Tobyhanna AD

COMMODITY PRODUCT	DEPOT
Communications/Electronics	
Shelter/Housing	Anniston AD
	Letterkenny AD
	MCLB Albany
	MCLB Barstow
	NAVWPNSTA Charleston
	NAVWPNSTA Yorktown
	NUWC Keyport Division
	Ogden ALC
	Sacramento ALC
	Tobyhanna AD
	Tooele AD

		Warner Robins ALC
	Support Equipment	Charleston NSY Mare Island NSY MCLB Albany MCLB Barstow NADEP Alameda NADEP Jacksonville NADEP Norfolk NADEP Pensacola NESEC San Diego Ogden ALC Philadelphia NSY Portsmouth NSY Puget Sound NSY Sacramento ALC Tobyhanna AD Tooele AD
Construction Equipment		
	Accessories and Components	Anniston AD Letterkenny AD MCLB Albany Tooele AD

COMMODITY	PRODUCT	DEPOT
Construction Equipment		
	Communications	MCLB Albany MCLB Barstow Tobyhanna AD MCLB Albany MCLB Barstow
	Electronics	Tobyhanna AD
	Engine	Anniston AD Letterkenny AD MCLB Albany MCLB Barstow Tooele AD

Hull & Chassis	Anniston AD Letterkenny AD MCLB Albany MCLB Barstow Tooele AD
General Support Equipment	
Accessories and Components	AGMC Newark Letterkenny AD MCLB Albany MCLB Barstow NADEP Cherry Point NADEP Norfolk NADEP North Island NADEP Pensacola Ogden ALC Oklahoma City ALC Sacramento ALC San Antonio ALC Tobyhanna AD Tooele AD

COMMODITY PRODUCT	DEPOT
General Support Equipment	
Electronic Test Equipment	Letterkenny AD MCLB Albany MCLB Barstow Ogden ALC Sacramento ALC Tobyhanna AD Tooele AD
Heating & Air Conditioning	Letterkenny AD Tooele AD
Machine Tools	NADEP Norfolk Ogden ALC Sacramento ALC Tooele AD

COMMODITY	PRODUCT	DEPOT
		Warner Robins ALC
	Power Plant/Generator Set GTE	MCLB Barstow NADEP Alameda NADEP Cherry Point NADEP Norfolk Ogden ALC Sacramento ALC Tobyhanna AD
	Power Plant/Generator Set Recip	MCLB Albany MCLB Barstow NADEP Cherry Point Ogden ALC Sacramento ALC Tobyhanna AD
	Rail Equipment - Locomotives	Tooele AD
	Rail Equipment - Rolling Stock	Tooele AD
	Topographic	Tooele AD

COMMODITY	PRODUCT	DEPOT
General Support Equipment		
	Troop Support Equipment	Anniston AD Ogden ALC Tooele AD Warner Robins ALC
Missile		
	Accessories and Components	AMARC Tucson Letterkenny AD NADEP Alameda NADEP Cherry Point NADEP Norfolk Ogden ALC Tooele AD
	GTE Propulsion	AMARC Tucson

		Ogden ALC Tooele AD
	Guidance System	Anniston AD Letterkenny AD NADEP Alameda NADEP Norfolk NAVWPNSTA Charleston NAVWPNSTA Seal Beach Ogden ALC Tobyhanna AD Tooele AD
	Missile Frame	AMARC Tucson Letterkenny AD NADEP Alameda NADEP Cherry Point NADEP Norfolk NAVWPNSTA Yorktown NUWC Keyport Division Tooele AD

COMMODITY	PRODUCT	DEPOT
Missile		
	Payload System	Letterkenny AD Tooele AD
	Solid Propulsion	Letterkenny AD NSWC Indian Head Div. Tooele AD
	Support & Launch	AMARC Tucson Charleston NSY Letterkenny AD Long Beach NSY MCLB Barstow NADEP North Island Ogden ALC Puget Sound NSY Tobyhanna AD Tooele AD

	Surface Command & Control	AMARC Tucson Letterkenny AD MCLB Barstow NADEP Alameda Ogden ALC Tobyhanna AD Tooele AD
Ordnance		
	Accessories and Components	Letterkenny AD MCLB Albany MCLB Barstow NADEP Alameda NADEP Cherry Point NADEP Norfolk Tobyhanna AD Tooele AD
	Chemical & Bacteriological Weapons	Tooele AD

COMMODITY	PRODUCT	DEPOT
Ordnance		
	Conventional Arms & Explosives	Letterkenny AD MCLB Albany MCLB Barstow NADEP Alameda NADEP Jacksonville NAVWPNSTA Charleston NAVWPNSTA Yorktown NUWC Keyport Division Ogden ALC Tooele AD
	Engines	Letterkenny AD MCLB Albany MCLB Barstow Tooele AD
	Guns & Artillery	Letterkenny AD MCLB Albany MCLB Barstow NADEP Alameda

		NADEP Cherry Point
		NADEP Norfolk
	Small Arms	Letterkenny AD
		MCLB Albany
		MCLB Barstow
		NADEP Alameda
		NADEP Cherry Point
		NADEP Norfolk
		NAVWPNSTA Charleston
		NSWC Crane Division
		Ogden ALC
Ships		
	Accessories and Components	Letterkenny AD
		Sacramento ALC
		Tooele AD
COMMODITY		
	PRODUCT	DEPOT
Ships		
	Armament	Charleston NSY
		Long Beach NSY
		Portsmouth NSY
		Puget Sound NSY
	Communications & Electronics	Charleston NSY
		Portsmouth NSY
		Puget Sound NSY
		Tobyhanna AD
	Fire Control	Charleston NSY
		Long Beach NSY
		Portsmouth NSY
		Puget Sound NSY
		Tobyhanna AD
	General Purpose	Charleston NSY
		Long Beach NSY
		Mare Island NSY
		Pearl Harbor NSY
		Portsmouth NSY
		Puget Sound NSY

	Sacramento ALC
Mechanical	Charleston NSY Norfolk NSY Portsmouth NSY Puget Sound NSY
Recip Engine	Tooele AD
Sub-Surface Hull	NUWC Keyport Division

APPENDIX IV

JOINT PAINT REMOVAL STUDY
POINTS OF CONTACT

JOINT TECHNOLOGY EXCHANGE GROUP PRINCIPALS

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(WHEAT STARCH BLASTING)

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SODIUM BICARBONATE

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